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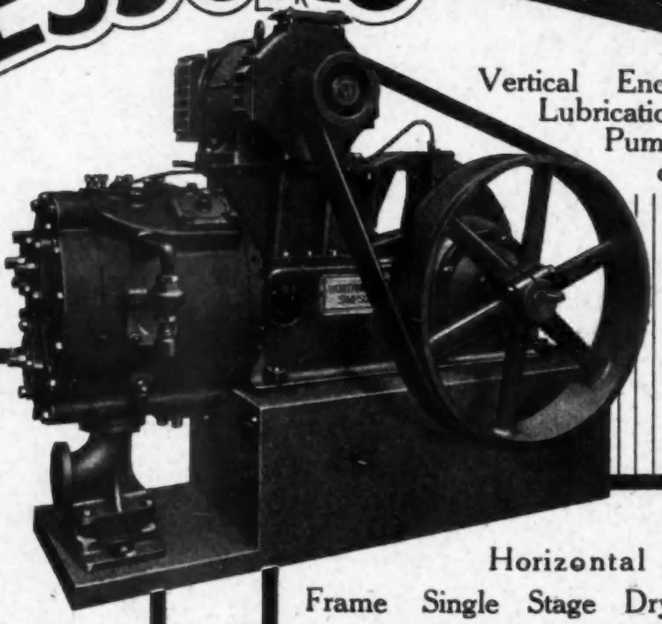

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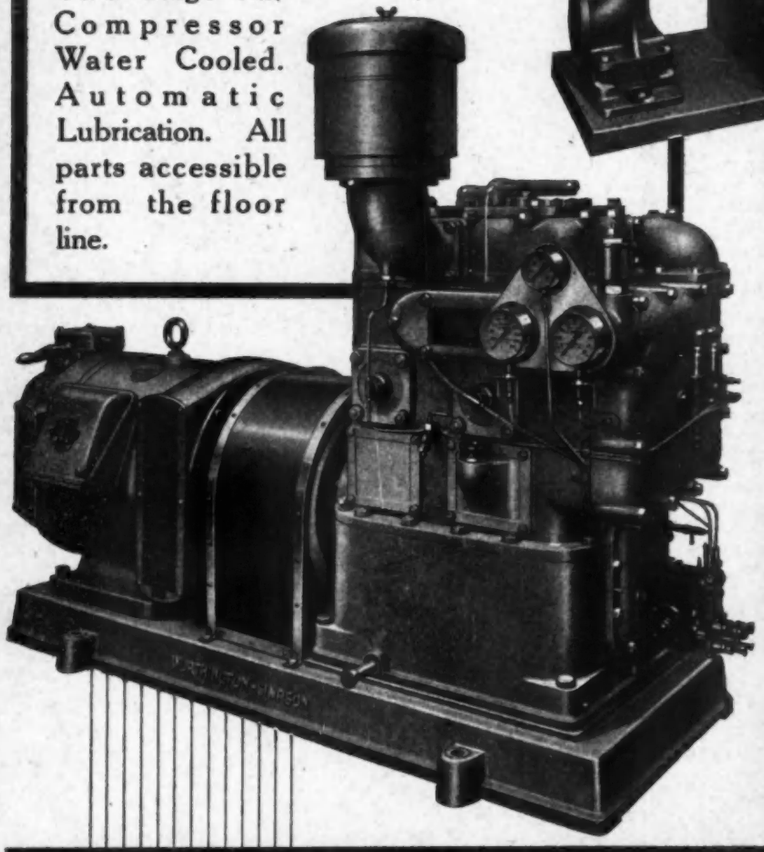

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TOOL DYNAMOMETER FOR MEASURING RAPID FORCE FLUCTUATIONS.

By RONALD N. ARNOLD, B.Sc., A.R.T.C., Ph.D., M.S., A.M.I.Mech.E.

THE history of metal cutting has placed on record many examples of tool dynamometers. These instruments, designed to measure the working forces imposed on cutting tools, are of varied design, and each is characterised by a certain individuality. Fundamentally, however, they may be grouped in relation to the particular method employed to register the forces, the details of design being a secondary, yet no less vital, consideration. Looked at in this way, three main types emerge, namely, mechanical, hydraulic, and electrical. A very brief survey of these seems appropriate before describing a further design recently developed to record high-frequency phenomena.

Mechanical.—As far back as 1880, Professor R. H. Smith* constructed a dynamometer by which he was able to measure the vertical cutting forces on lathe tools. Simplicity marked this early design, the force being weighed by means of a long steelyard attached to the tool-holder. Hardened-steel keys sustained the load until balance was attained. Later investigators devised methods for recording simultaneously, the three force components. Mechanical recording, however, seems to have been overlooked until 1936, when it was revived by Boston and Kraus.† Their method involved the measurement of the component deflections of the tool-holder, together with the deflection of a diaphragm used to sustain the radial load. Small lever systems were employed to magnify these movements, final measurement being recorded by dial gauges.

Hydraulic.—The main credit for hydraulic recording must be given to Dr. J. T. Nicolson,‡ who worked for many years overcoming difficulties and published an account of his work in 1904. Each recording element of his dynamometer consisted of a small container filled with distilled water, the internal pressure of which was recorded by a Bourdon gauge. A diaphragm on each container supported the load, and varied the fluid pressure on deflection. In its final form the instrument successfully recorded the three force components, and later, in the hands of Dempster Smith,* produced results which are a credit to its designer. Many other dynamometers of this type have been used from time to time, notably by Donaldson,† Hyde‡ and Schlesinger§, but it is doubtful if any of these showed improvement on Nicolson's original design, and in some cases they were unable to record all the force components.

Electrical.—More recent designs seem to favour electrical means of force recording, and one of these, made by Schiess-Defries, Düsseldorf, became a commercial product and patents were applied for. The original pressure element for this device, designed and patented by Wallichs, was not unlike that adopted by Nicolson. In place of distilled water, however, Wallichs introduced an electrolyte and measured the internal pressure by the change in electrical resistance. Later, an electromagnetic method was adopted, in which deflections of a diaphragm caused alterations in the air-gap of a magnetic circuit. In 1932, Gechter and Laird designed an ingenious dynamometer in which they measured the forces by piezo-electric means. Quartz crystals formed the pressure elements, and the electrostatic charges produced under stress were received by an amplifier, and finally recorded by an oscillograph. By this means they were able to investigate rapid force variations.

Dynamometer.—In introducing a new design of tool-dynamometer it is well to explain the purpose of its development in view of the many designs already in existence. The problem confronting the author was that of recording extremely rapid force fluctuations such as exist under "chatter" and intermittent cutting. Of the dynamometers already described, only the electrical group can approach such demands, but these, if not limited by the electrical recording, were limited by their own natural frequency. None of these dynamometers, in fact, appeared to be capable of recording frequencies of over 50 cycles per second, and as it was desired to record frequencies up to 1,500 cycles per second a new design had to be adopted. Three guiding principles controlled the design, namely: (1) the strain-recording mechanism should be capable of recording frequencies of the order of 5,000 cycles per second. (2) The dynamometer masses should be arranged to give as high a natural frequency as possible without prejudicing strength and accuracy of strain measurement. (3) Errors due to secondary strains arising from the interaction of the component forces should be limited to 5 per cent.

Two alternative schemes were chosen to satisfy condition (1), each associated with the name of Professor A. V. de Forest, of Massachusetts Institute of Technology. The first makes use of a scratch-extensometer* and the second of an iso-elastic

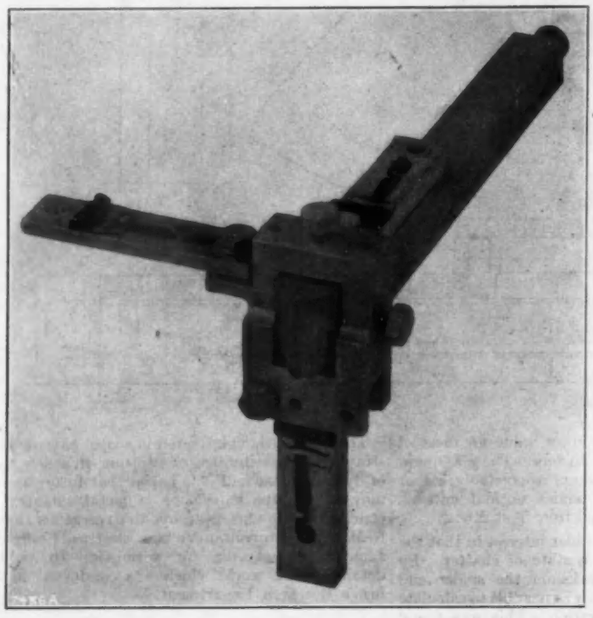


FIG. 1. TOOL HOLDER WITH STRAIN ELEMENTS AND EXTENSOMETERS IN POSITION.

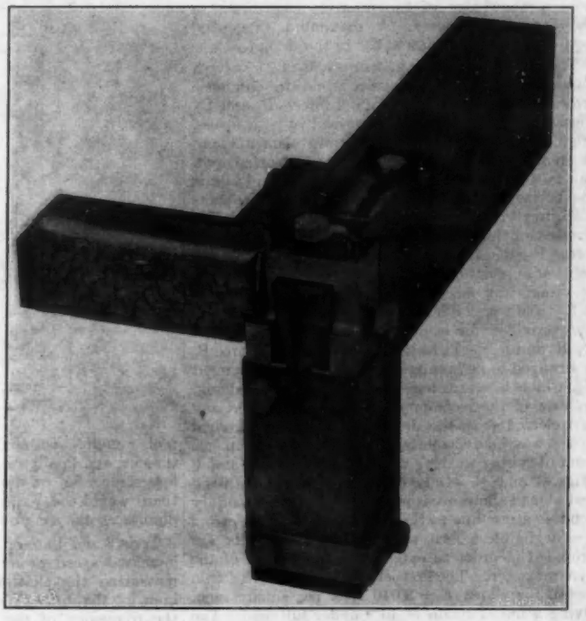


FIG. 2. TOOL DYNAMOMETER ASSEMBLED FOR TEST.

TABLE I.—RESULTS OF TESTS.

Test.	Depth of Cut. Inches.	Feed. Inches.	R.p.m.	Cutting Speed. Ft. per Minute.	Forces. Tons. P_1.	P_2.	P_3.	Estimated Force P_1 for Normal Cutting. Tons.
1	0·375	0·013	23	136	0·57	0·11	0·15	0·48
2	0·375	0·0185	23	136	0·77	0·19	0·22	0·67
3	0·375	0·0075	35	207	0·63	0·39	0·27	0·29
4	0·375	0·0075	48	284	1·15	0·57	0·32	0·29

* Smith, R. H., *Cutting Tools*, 1st edition, Cassell and Company (1882).

† Boston, O. W., and Kraus, C. E., "A Study of the Turning of Steel Employing a New-Type Three-Component Dynamometer," *Trans. A.S.M.E.*, vol. 58, No. 1, page 55.

‡ Nicolson, J. T., "Experiments with a Lathe-Tool Dynamometer," *Proc.I.Mech.E.*, 1904, page 883; ENGINEERING, vol. 78, page 675 (1904).

* Smith, Dempster, "Cutting Tools," *Trans. Manchester Assoc. of Engrs.*, 1911-12, page 133.

† Donaldson, H. F., "Cutting Angles of Tools for Metal Work," *Proc.I.Mech.E.*, 1903, page 5; ENGINEERING, vol. 85, pages 98, 124 (1903).

‡ Stanton, T. E., and Hyde, J. H., "Cutting Tools Research," ENGINEERING, vol. 119, page 148 (1925).

§ Schlesinger, G., "Machine Tool Tests and Alignments," *Proc.I.Mech.E.*, 1938, vol. 138, page 59; ENGINEERING, vol. 145, pages 104, 134, 162 (1938).

‖ Gechter, O. F., and Laird, H. R., "Improved Device for Recording Instantaneous Tool Pressures," *Trans. A.S.M.E.*, vol. 54, No. 12, page 73.

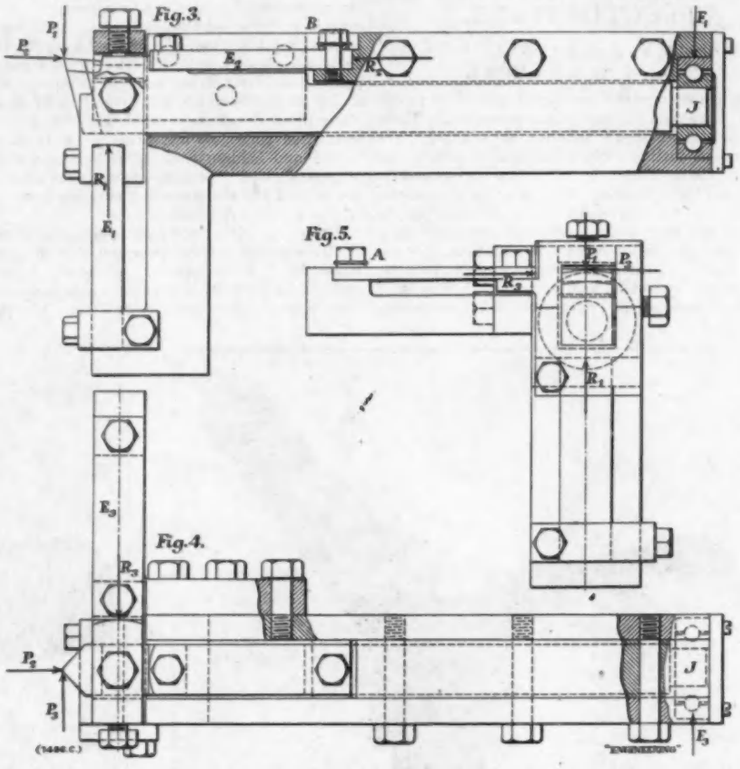
* Arnold, R. N., "Impact Stresses in a Freely Supported Beam," *Proc. I. Mech. E.*, 1937, vol. 137, page 225.

DYNAMOMETER FOR FORCES ON CUTTING TOOLS

resistor, both having proved capable of recording at least 7,000 vibrations per second. The present article confines itself to results obtained by the former method, the development of the electrical recording being still in progress. The mechanical design which finally emerged is illustrated by the photographs reproduced in Figs. 1 and 2, page 221, and by the drawings, Figs. 3, 4 and 5, annexed. Fig. 1 shows the special tool-shank with its three Elektron strain elements in position; these are lettered E_1, E_2 and E_3 in Figs. 3 and 4. The compressive strains of these bars record, respectively, the tangential, radial, and axial force components, and are measured by scratch-extensometers. These little instruments, shown attached to the elements in Figs. 1 and 2, trace minute scratches on a polished metal target, the records being finally examined under a microscope. It will be observed that the strain elements have different cross-sectional areas. These were introduced in order to record comparable strains in all three directions, the areas being deduced from a knowledge of the relative magnitudes of the force components. A maximum tangential load of 2 tons was allowed for in the design.

The mechanics of the instrument is not involved, though careful design was required to eliminate errors. The tangential and axial forces, P_1 and P_3, Figs. 3, 4 and 5, are each sustained by two forces, originating at the respective strain elements and the rear journal J. This journal is supported by a ball-race in the main frame (see Fig. 3), and allows the horizontal movement due to force P_2 to take place freely. To avoid the introduction of bending stresses on the elements it was necessary to arrange forces P_1, R_1 and F_1 as a coplanar system. As the point of application of P_1 depends on the tool shape, provision was made for adjusting the disposition of R_1 to suit prevailing conditions. Adjustment was also provided for element E_2 in order that forces P_2, R_2 and F_2 might be in the same plane. Force P_2 is arranged to be approximately in line with element E_2, which is connected directly to the tool shank. In view of the secondary stresses produced on any two elements by the deflection of the third, rigid fixing was inadvisable and elastic supports in the form of rubber washers were introduced at A and B (Figs. 3 and 5). Only element E_1 is rigidly fixed and a small allowance is made at E_1 for the secondary bending stress due to the strain in E_2. Other errors are negligible. Two sets of strain elements are provided in order to extend the capabilities of the dynamometer. The first set is composed of Elektron metal, for which $E = 3{,}040$ tons per square inch, giving a unital strain of 10^{-3} under full load. The minimum natural frequency of the instrument when fitted with Elektron has been calculated as 1,850 v.p.s. For recording higher frequencies the steel elements may be employed giving a natural frequency of 3,730 v.p.s., but accuracy is then impaired owing to difficulties of strain measurement. It is hoped, however, that increased sensitivity may be obtained by use of electrical recording.

Preliminary tests were carried out to ascertain the capabilities of the dynamometer, strain measurements being taken by scratch-extensometer. For these tests a mild-steel spider was chosen with a Brinell hardness of 110. It consisted of four plates 2 in. thick welded to a 6-in. diameter boss, and had an outside diameter of approximately 23 in. The machining was performed on a 16-in. Ward turret lathe, and the tool used had a 45-deg. plan angle, a 5-deg. top rake, and a carbide tip of "Cutanit S." Four tests were conducted with a constant depth of cut of $\frac{3}{4}$ in., particulars of which are given in Table I, page 221. The forces in all cases were obtained from the average dimensions of a number of scratch-records. These were measured under a powerful microscope and micro-photographs of a few representative scratches are reproduced in Figs. 6 to 10, on Plate XVII. It must be emphasised that owing to the arbitrary movement of the extensometer arms the time scale of these records is quite erratic. Fig. 6 illustrates the strains recorded in each element during Test 1, each cycle representing the change of force on the tool during the cutting of one arm of the spider. The lack of a true time scale prevents rigid interpretation of these diagrams, but it seems evident from the contours of (*a*) that the force rises to a maximum on the entry of the tool, remains at a slightly lower value for most of the cut, and finally returns to zero. The maximum forces recorded in this test are appreciably higher than would be expected under normal cutting. Similar results were obtained from Test 2.



Tests 3 and 4 are of particular interest in that the increased speed promoted a state of chatter. By measuring the chatter marks on the spider and knowing the cutting speed it was possible to calculate the frequency of the vibration. This was found to be 900 v.p.s. and was identified by calculation as the lateral vibration of the arm of the spider. Representative records from Test 3 are shown in Figs. 7 to 10. Of these, Fig. 7 is reproduced from a photograph at moderate magnification in which is depicted the history of chatter during the cutting of one arm of the spider. Each wave represents the variation of force during one chatter vibration and corresponds to a time interval of approximately 0·001 second. It is of interest to note the way in which this vibration is built up from the commencement of cutting, a process which may be understood more fully from Figs. 8, 9 and 10. These photographs were taken at much higher magnification and seem to show that the start of the vibration is preceded by complex force variation at the instant of tool entry. The steady increase in amplitude of the waves is characteristic of a forced vibration, which, in the case of chatter, is self-induced. It should be mentioned that the maximum amplitudes attained were found to vary considerably, but this was not unexpected in view of the critical conditions which existed. Reference to the results will show, however, that the cutting forces under chatter may reach very much higher amplitudes than those obtained under normal cutting, and this may explain why its presence greatly reduces the working life of a tool. As a further illustration, Fig. 11, Plate XVII, is reproduced to show the actual chatter contour as displayed on the arm of the spider, each wave being approximately $\frac{1}{16}$ in. long. An increase in vibration amplitude similar to that obtained from the dynamometer is evident in this illustration, entry of the tool occurring on the right and proceeding in the direction of the arrow.

These tests, though limited in scope, have demonstrated the possibilities of utilising this new type of dynamometer and it is hoped that future results may add to the knowledge of metal cutting. In conclusion, the author desires to express his thanks to Messrs. Metropolitan-Vickers Electrical Company, Limited, Manchester, for permission to publish details of this work, which was conducted in the firm's Research Department.

REGISTRATION OF FORMER SHIPYARD WORKERS.—To enable the Ministry of Labour and National Service to trace the large numbers of skilled shipyard workers who left the industry during the years of depression, and to arrange that those not already employed on work of equal or greater national importance should return to shipbuilding, ship-repairing, and the associated industries, the Minister (Mr. Ernest Bevin) has made an Order, under Defence Regulation 58A, requiring that all male persons possessing certain specified qualifications shall register at their local employment exchanges. The Order, which is entitled the Industrial Registration (No. 1) Order, 1941, applies to persons aged 20 years or over, who have been employed, during the past 15 years, for an aggregate period of not less than twelve months, in any of the following occupations: angle-iron smith, angle-iron smith's striker or hammerman; blacksmith (ship), or blacksmith's striker or finisher (ship); boiler-maker (ship); boiler fitter or mounter, boiler pipe or tube fitter or expander, boiler coverer or scaler (ship); cementer, concreter (shipyard); coppersmith (shipyard); craneman (shipyard); draughtsman (ship); driller or countersinker (machine or hand) (ship); electrician, wireman or electrician's labourer (ship) fitter or fitter's labourer (ship); iron caulker, tank tester, felter or packer; painter (ship), red leader, scaler; plater, slipper; plater's helper (ship); plumber or plumber's mate (ship); rigger, sailorman; riveter, holder-up, bumper-up, rivet heater; sheet-metal worker or sheet-iron worker (shipyard); ship joiner or ship carpenter; shipwright or shipwright's labourer; boat, barge or yacht builder; boatwright; block or spar maker; loftsman; liner-off; stager; timekeeper, piece-work counter or wages clerk (shipyard); electric welder (ship), burner or cutter. The latest date for registration is March 22, but this is applicable only to those who have been prevented from registering before March 19, the general closing date. Present shipyard employees need not register.

TOOL DYNAMOMETER FOR RAPID FORCE FLUCTUATIONS.

(For Description, see Page 221.)

(To face page 222.)

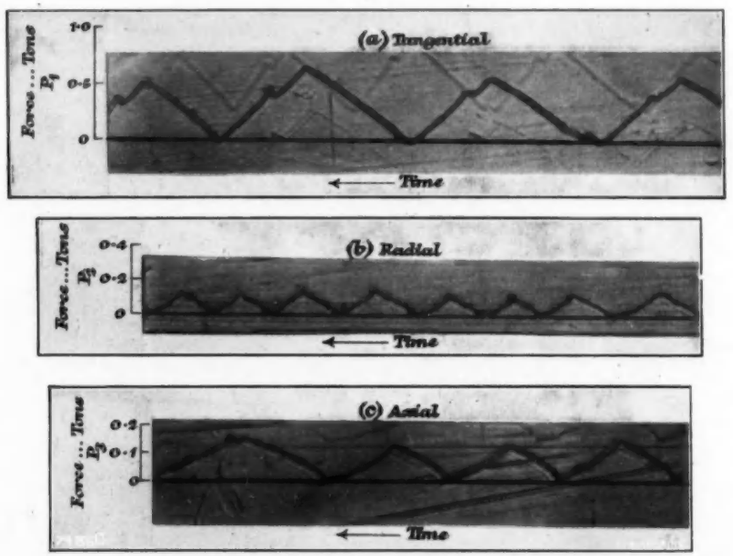


FIG. 6. FORCE RECORDS. DEPTH OF CUT, 0·375 IN.; FEED, 0·013 in.; CUTTING SPEED, 136 FT. PER MINUTE.

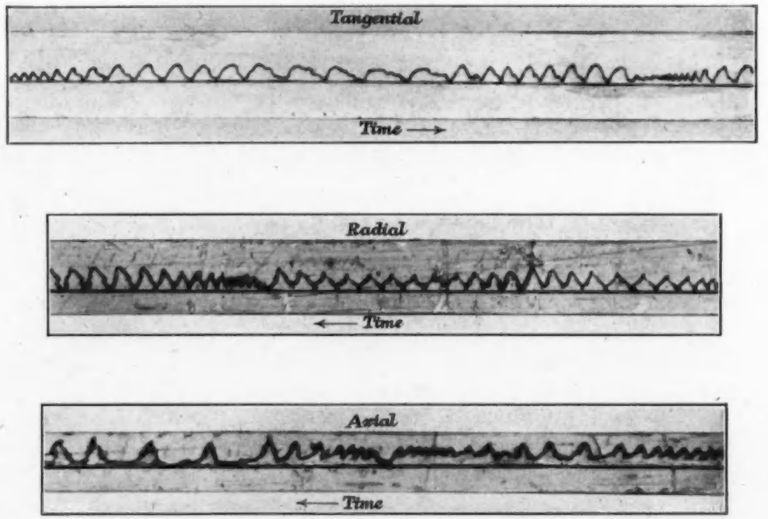


FIG. 7. STRAIN RECORDS WITH "CHATTER." DEPTH OF CUT, 0·375 IN.; FEED, 0·0075 IN.; CUTTING SPEED, 207 FT. PER MINUTE; VIBRATION FREQUENCY, 900 PER SECOND.

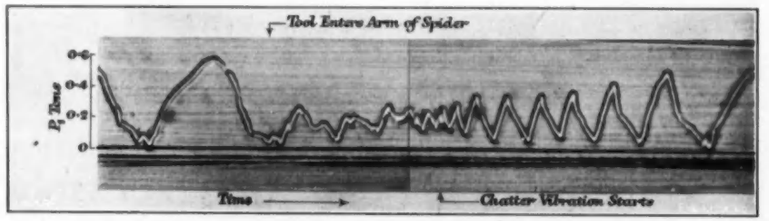


FIG. 8. TANGENTIAL FORCE WITH "CHATTER." VIBRATION FREQUENCY, 900 PER SECOND.

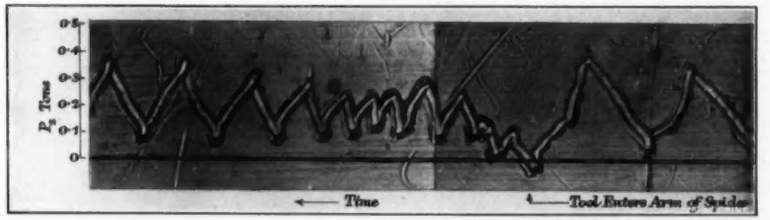


FIG. 9. RADIAL FORCE WITH "CHATTER." VIBRATION FREQUENCY, 900 PER SECOND.

FIG. 10. AXIAL FORCE WITH "CHATTER." VIBRATION FREQUENCY, 900 PER SECOND.

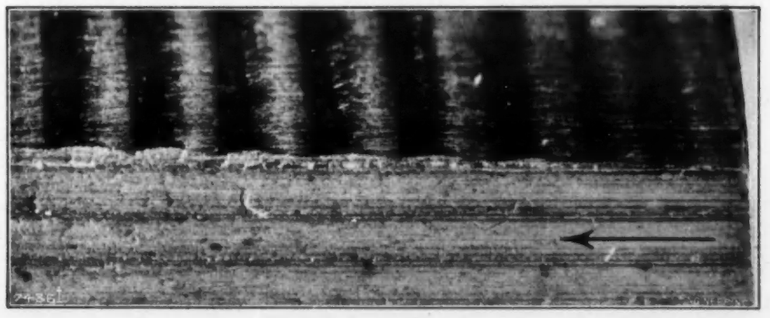


FIG. 11. "CHATTER" MARKS ON SPIDER.

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THE ENGINEERING OUTLOOK.

V.—Machine Tools.

The machine-tool industry recorded a further rapid expansion of output during the past year, and production was only limited by the rate at which new plants could be completed and by the limitations imposed by the available supplies of raw materials and of labour. The industry was engaged almost exclusively on Government work; many firms reported cancellation of their civil contracts on the outbreak of war, while, at the same time, the Government requisitioned many of the tools which were under construction for export orders. In the absence of production or employment statistics, it is impossible to assess at all accurately the degree to which output has been expanded; but, although the experience of individual firms undoubtedly varied widely, it is significant that, in July, 1940, the chairman of Greenwood and Batley, Limited, stated that, during the previous twelve months, the number of the company's employees had increased by 150 per cent.

The expansion in output was not achieved without difficulties; in particular, machine-tool makers appear to have suffered severely from the poaching of skilled workers, referred to in other articles in this series. The chairman of the Scottish Machine Tool Company, speaking in June, attributed the fall in the profits of the company, among other factors, to the loss of numbers of key men from the various factories, as a result of the shortage of skilled labour and the competition which arose between the armaments and other factories engaged on Government orders. A month earlier, several manufacturers had informed the Machine Tool Trades Association that they were falling behind in deliveries owing to this practice of poaching skilled labour. They complained mostly of some of the more recently formed companies, who were said to be offering every inducement to attract men from the older-established firms, though it was also stated that some Government establishments were not entirely guiltless. The companies also complained that the poaching firms were not taking their share of trainee labour and pointed out that, although the Ministry of Labour was obtaining good results at the training centres, such men were inevitably somewhat raw in the early stages. As pointed out in the first article in this series, dealing with the engineering industry as a whole, there appears to have been a substantial improvement in the position regarding labour poaching towards the end of the year.

In past years, this country has always obtained an appreciable quantity of machine tools from Germany. The cutting off of this source of supply made it necessary, not only to expand production in this country to the maximum possible extent, but also to take all steps to expand imports from the other principal source of supply in peace time, namely, the United States. Towards the end of May, 1940, in order to secure the greatest possible deliveries from the United States with the least possible upset of prices and delivery dates, the Controller of Machine Tools sent a circular to all Government departments and importers of machine tools, giving details of new arrangements designed to co-ordinate British demands on the American machine-tool builders. The plan provided that all purchases of new machine tools in the United States should be made by the British Supply Board in Canada and the United States. Purchasers in the United Kingdom were asked to follow normal commercial practice in placing contracts with agents registered with the Machine Tool Control. These agents continued to be responsible for the usual pre-sale and post-sale service arrangements and for giving advice as to prices and delivery dates, and were responsible for forwarding the order to the British Purchasing Commission in New York. Under the scheme, all orders had to be sponsored by a Government department, public utility company or local authority.

No statistics of imports of machine tools have been published since the outbreak of war, but recently published details regarding the United States machine-tool industry throw some light on the degree of expansion which has been achieved. In January, 1941, the results were published by the National Machine Tool Builders' Association of a survey of the activities of 115 machine-tool companies, comprising 80 per cent. of the United States industry's capacity. This revealed that, during the first year of the war, the total output of the industry had more than doubled, from 200 million dols. in 1939 to an estimated figure of 425 million dols. in 1940. It was further estimated that production in 1941 would be in excess of 600 million dols. Sixty-five of the 115 companies had built plant additions during 1940, almost entirely without financial assistance from the Government. The total estimated expansion of capacity during the first year of war was put at 50 per cent., the inference being that the capacity in existence before the outbreak of war was not fully employed. The total number employed in the industry at the end of 1940 was 80,000, of which almost half had been trained since September, 1939. An extensive system of sub-contracting had been developed, under which 86 of the 115 companies were having parts manufactured by sub-contractors, while 33 were farming out sub-assemblies. In addition, it was found that 23 firms were having complete machines manufactured by other companies, the most outstanding example being the Kearney and Trecker Corporation, of Milwaukee, makers of milling machines, who were having 500 complete machines built by the Westinghouse Company at Pittsburgh and another 500 by the Miehle Printing Press Company.

The total value of orders on hand at the end of 1940 was 400 million dols., of which 65 per cent. was for United States defence work, 21 per cent. for Great Britain, 2·6 per cent. for Canada, and a large part of the remainder for use by the machine-tool builders themselves, in expanding capacity. According to the United States trade returns, total exports of power-driven metal-working machinery increased from 91 million dols. in the first ten months of 1939 to 190 million dols. in the corresponding period in 1940. Although figures are not available for exports to individual countries, it is probable that a high proportion of the increase was accounted for by exports to the United Kingdom.

In December, further steps were taken to secure a substantial increase in production in the United States. In the first place, a virtual embargo was imposed on exports (except those required for the British defence programme) through the extension of the export licensing system to cover 41 types of tools not previously covered. In addition, a wide programme was put in hand for the discovery of unused productive facilities throughout the country, and for a further extension of sub-contracting. The War Department announced that it would finance the expansion of seven different machine-tool factories, four of them especially for the manufacture of vitally needed gauges.

The war has inevitably caused a substantial decline in British exports of machine tools. A dangerously high proportion of pre-war exports went to Russia, which is now obtaining large supplies of machine tools from Germany. The cutting off of German exports to overseas countries, however, probably would have enabled British manufacturers to make good this loss, had the capacity of the industry been sufficient to meet both the rapidly expanded home demand and the potential export demand. Actually, so great was the demand for machine tools for the equipment of armament factories in this country that, as stated above, the Government were compelled to requisition many tools on order for export markets, and, during the past year, exports have been severely controlled. Most manufacturers have been able to devote only a very small proportion of their resources to meeting export orders.

No statistics of exports are available for 1940, but the figures up to the end of 1939, by classes, are given in Table I, herewith, and the monthly averages in Table II, also on this page. The latter table shows that, during the first four months of the war, exports were reduced to a rate equal to about half that prevailing during the first eight months of the year, but, in spite of this, exports for the whole of 1939 exceeded those for the previous year. Total exports for 1939 amounted to 27,453 tons, valued at 4,579,000*l.*, compared with 24,167 tons, valued at 4,476,000*l.*, in 1938. The most marked reduction in exports as a result of the war occurred in the case of boring mills, milling machines, planing and shaping machines, presses and punching and shearing machines, but exports of grinding machines, drilling machines and lathes were also substantially reduced. The rate of export of unspecified types of tools, on the other hand, increased considerably during the first four months of the war. This category is composed mainly of simple types, of a low average value per ton. An examination of the destination of exports for the

TABLE I.—United Kingdom Exports of Machine Tools, by Classes.

	Tons.				Value, £000.			
	1938.	1939.	1939, Jan.-Aug.	1939, Sept.-Dec.	1938.	1939.	1939, Jan.-Aug.	1939, Sept.-Dec.
Boring mills	1,672	1,433	1,290	143	235	195	171	24
Drilling machines	2,534	2,027	1,664	363	445	337	280	57
Grinding machines	2,788	2,129	1,810	319	733	533	449	84
Lathes	6,734	7,928	6,568	1,360	1,446	1,636	1,350	286
Milling machines	1,798	1,855	1,652	203	424	495	437	58
Planing and shaping machines	3,546	3,991	3,563	428	421	440	387	53
Presses and punching and shearing machines	1,445	2,560	2,288	272	140	227	185	42
Other sorts	3,650	5,530	3,313	2,217	682	716	455	261
Total	24,167	27,453	22,148	5,305	4,476	4,579	3,714	865

TABLE II.—*Machine Tools: United Kingdom Exports (Monthly Averages.)*

	Volume.	Index. 1913=100.	Value per Ton.	Index. 1913=100.
	Tons.		£	
1913	1,378	100	61·2	100
1931—				
1st Quarter	998	72	150·6	246
2nd ,,	982	71	146·7	239
3rd ,,	1,019	73	135·5	218
4th ,,	1,874	136	137·0	223
1932—				
1st Quarter	2,020	147	134·6	220
2nd ,,	2,048	149	147·0	242
3rd ,,	2,133	155	113·6	186
4th ,,	1,742	126	129·4	211
1933—				
1st Quarter	1,006	73	152·3	249
2nd ,,	803	58	145·0	237
3rd ,,	565	41	133·4	218
4th ,,	593	43	130·4	213
1934—				
1st Quarter	689	50	131·5	215
2nd ,,	1,150	84	123·3	201
3rd ,,	1,201	87	134·1	219
4th ,,	1,033	75	141·0	230
1935—				
1st Quarter	1,427	103	133·8	219
2nd ,,	1,413	102	128·6	210
3rd ,,	1,346	98	133·9	219
4th ,,	1,316	95	148·8	243
1936—				
1st Quarter	1,044	76	146·7	240
2nd ,,	1,326	96	140·6	230
3rd ,,	1,078	78	150·0	245
4th ,,	1,182	86	144·8	236
1937—				
1st Quarter	842	61	171·9	280
2nd ,,	886	64	182·4	298
3rd ,,	1,055	77	170·7	279
4th ,,	1,183	86	195·4	319
1938—				
1st Quarter	1,345	98	193·2	316
2nd ,,	1,891	137	176·6	288
3rd ,,	2,118	154	189·5	310
4th ,,	2,701	196	184·1	301
1939—				
1st Quarter	2,999	217	164·4	268
2nd ,,	2,532	184	180·2	299
July-August	2,777	201	157·8	256
September - December	1,326	96	163·1	266

whole of 1939 shows that Russia was the largest individual market, taking 14,344 tons out of the total of 27,453 tons. Russia took 12,168 tons before the outbreak of war, but only 2,176 tons during the last four months of the year, showing, as might have been expected, that the war caused a sharp decline in the value of this market. The second most important market in 1939 was Australia, which took 3,172 tons (2,468 tons before the outbreak of war and 704 tons thereafter): followed by France, which took 1,780 tons (1,084 tons before the war and 696 tons thereafter). The war thus caused an increase in the rate of exports to France. Exports to India and South Africa were also well maintained in spite of the war, probably mainly in connection with the equipment of armament factories in those countries. India took 980 tons during the first eight months of the year and 440 tons during the last four months, making a total for the year of 1,420 tons; while South Africa took 574 tons during the first eight months and 259 tons during the last four months, a total of 833 tons. The war occasioned an almost complete cessation of exports to Japan, which took 744 tons during the first eight months of 1939, but only 4 tons in the remainder of the year.

TABLE III.—UNITED KINGDOM EXPORTS OF TEXTILE MACHINERY, BY CLASSES.

	1938.	1939.	1939. Jan.-Aug.	1939. Sept.-Dec.	1938.	1939.	1939. Jan.-Aug.	1939. Sept.-Dec.
For spinning and twisting, including all preparatory processes	49,003	27,863	21,191	6,672	5,672	3,802	2,845	957
For processes preparatory to weaving, but subsequent to spinning and twisting	1,040	498	419	79	103	61	48	13
Looms and parts (excluding bobbins)	12,671	12,093	9,128	2,965	1,176	1,124	793	331
Printing and finishing	4,067	3,095	2,341	754	418	311	243	68
Hosiery and knitting	559	578	425	153	467	434	330	104
Parts and bobbins	1,558	1,498	1,019	479	294	218	149	69
All other sorts	2,087	1,850	1,235	615	296	262	174	88
Total	70,985	47,475	35,758	11,717	8,427	6,212	4,582	1,630

In the home market, in addition to the drive for increased production, there have been several developments designed to secure the more intensive utilisation of the tools already installed. In June, a census of machine tools was ordered in the engineering and allied industries. Information was asked for, not only in respect of types and of the purposes for which existing tools were being used, but also the number of hours daily during which they were in operation. This measure was generally welcomed, as it had been felt that an unduly high proportion of the machine tools in the country was far from being fully utilised. It was pointed out, however that a very much wider census was required than one covering only the engineering industry, since a large number of machine tools were to be found in the maintenance departments of other industries, and it was just these tools which were likely to be the least intensively employed.

At about the same time that the census was put in hand, however, a scheme was instituted to mobilise the machine tools and the mechanics employed in garages. These tools were to be used to create a factory at a central point in each of seventeen areas, and the garage proprietors owning the tools and premises were to control the works. On July 9, the Under-Secretary to the Ministry of Supply stated in the House of Commons that the census of machine tools had been recently completed. At the same time it was stated that the Government had had no occasion to use compulsory powers in order to secure better utilisation of machine tools because in every instance it had been found possible to make amicable arrangements between the owners of the tools and those who wished to use them.

Towards the end of July, a strict control was imposed on the sale of second-hand machine tools. Maximum prices were fixed, and all dealers in second-hand machine tools were required to register with the Ministry of Supply and to keep a record of all dealings. The order also enacted that, as from August 17, no dealings would be authorised except under licence from the Ministry. Under a previous order, maximum prices had been fixed for new machine tools. In August, an appeal was made to firms to surrender unused or only partially-used machines. Only a few days later, the Minister of Supply was able to announce that 3,000 firms had already responded and that a large volume of offers continued to be received. Many firms stated that they were replanning their shops in order to be able to spare the largest possible number of tools. In December, it was stated that 4,000 machine tools had been voluntarily surrendered. In the first week in November it was decided to repeat the census, with the primary object of determining whether the change-over which had occurred in the activities of a large number of firms had resulted in freeing any further tools, and also to keep up to date the information required to locate at once the works where a particular job could be undertaken or where machinery existed to supplement capacity elsewhere.

There has also been a rapid expansion of production of machine tools in Australia. At the outbreak of war there were only two manufacturers of power presses and one of lathes in the country, which was dependent largely on imports from the United Kingdom, the United States, and Germany. Within twelve months, however, a machine-tool industry comprising 28 firms had been built up, which was producing 3,300 machines, valued at £A.2,000,000. Power presses are being made with capacities up to 5,000 tons, and considerable numbers of cartridge machines and shell lathes are being produced.

TABLE IV.—*Textile Machinery: United Kingdom Exports.* (*Monthly Averages.*)

	Volume.	Index. 1913=100.	Value per Ton.	Index. 1913=100.
	Tons.		£	
1913	14,840	100	46·5	100
1932—				
1st Quarter	5,472	36·9	87·2	187·5
2nd "	5,666	38·2	86·3	185·6
3rd "	4,796	32·3	89·0	191·4
4th "	5,089	34·3	87·0	187·1
1933—				
1st Quarter	4,492	30·3	95·3	204·9
2nd "	4,514	30·4	95·2	204·7
3rd "	4,193	28·3	95·5	205·6
4th "	5,695	37·8	83·3	179·1
1934—				
1st Quarter	6,876	46·3	76·1	163·6
2nd "	6,780	45·7	85·8	184·5
3rd "	5,884	39·6	89·6	192·7
4th "	6,622	44·6	89·4	192·3
1935—				
1st Quarter	5,821	39·2	101·6	218·5
2nd "	5,703	38·4	102·2	220·0
3rd "	5,303	35·7	101·9	219·0
4th "	5,497	37·0	106·0	228·0
1936—				
1st Quarter	4,686	31·6	109·1	234·8
2nd "	4,057	27·3	118·0	254·0
3rd "	4,387	29·6	110·0	236·5
4th "	4,612	31·0	111·7	240·0
1937—				
1st Quarter	4,668	31·5	117·1	251·8
2nd "	5,538	37·3	114·7	246·7
3rd "	6,303	42·5	113·6	244·3
4th "	7,567	51·0	106·9	229·9
1938—				
1st Quarter	7,451	50·2	109·8	235·6
2nd "	5,867	39·5	120·7	259·4
3rd "	5,222	35·1	121·4	261·0
4th "	5,022	33·8	127·3	273·7
1939—				
1st Quarter	4,765	32·0	122·1	262·1
2nd "	4,274	28·8	133·1	282·5
July-August	4,321	29·2	130·7	281·2
September - December	2,929	19·7	139·1	290·1

VI.—TEXTILE MACHINERY.

During the past year, most textile-machinery firms were engaged mainly on armament work and the production of textile machinery was not at a high level, either for the home market or for export. There was a fair demand, however, for replacements and repairs, as a result of the large orders placed by the Government with the textile industry to meet the requirements of the Forces. For a long time the industry has been mainly dependent on export orders and, in 1939, even before the outbreak of war, there was a substantial decline in exports compared with the previous year; this decline was accentuated by the war. Exports by classes of machinery are shown, up to the end of 1939, in Table III, herewith, while the monthly average for each quarter of the year is shown in Table IV. From the latter it can be seen that monthly average exports, which had been running at well over 5,000 tons during 1938, fell during the first eight months of 1939 to under 4,500 tons per month, while the outbreak of war caused a further fall to just under 3,000 tons during the last four months of the year. Figures are not available for 1940, but it is understood that India continued to be a relatively satisfactory market.

Table III shows that the decline in total exports during 1939 was largely due to the fall in exports of machinery for spinning and twisting and preparatory processes, exports of looms and parts were almost maintained at the 1938 level, and there was a small increase in exports of hosiery and knitting machinery; moreover, this increase continued during the first four months of the war. In peace time, Germany was a very important exporter of hosiery and knitting machinery, having a virtual monopoly in some classes. It is to be hoped that the British industry will take advantage of the elimination of German competition, not only to supply the needs of this country, but also to secure a leading position in export markets.

WAVES IN AN OPEN OSCILLATING TANK.

By A. M. BINNIE, M.A.

WHEN an open tank containing liquid is forced to perform angular oscillations about a fixed axis, waves are formed on the surface. The purpose of this article is to develop an approximate theory of these waves for the simple case when the tank is rectangular, and the fixed axis is parallel to one pair of the sides of the tank and perpendicular to the other. The liquid in the tank is taken to be inviscid and the analysis is restricted to small displacements. The results may be applied to the design of open tanks, such as swimming baths, carried on ships.

It is shown in text-books on hydrodynamics* that the "speed" p_s of free oscillations in a stationary rectangular tank of length $2a$ is given by

$$p_s^2 = \frac{s\pi g}{2a} \tanh \frac{s\pi h}{2a}, \quad . \quad . \quad . \quad (1)$$

where g is the acceleration due to gravity, h is the uniform depth, and $s = 1, 2, 3 \ldots$ In practice, only the gravest mode ($s = 1$) is of importance. Synchronism between these waves and the oscillations of the ship can be avoided, but information is required on the height of the waves at the ends of the tank and on the advantages to be gained by placing the tank below instead of above the centre of oscillation of the ship.

Theory of the Waves.—Treating the problem as two-dimensional, consider a rectangular tank, Fig. 1, opposite, of length $2a$ and of infinite width, containing liquid to a uniform depth h. The tank is fixed to a frame, which can rotate about the fixed axis O. The frame and tank are given symmetrical oscillations, the angular displacement being defined by $\theta = \theta_0 \sin pt$ (θ_0 being small) and the angular velocity by $\omega = \omega_0 \cos pt$, where $\omega_0 = p\theta_0$. It is desired to find the form of the waves set up, and, in particular, the elevation of the waves at $x = \pm a$, when the tank is at the end of its travel.

Using the rotating axes shown in Fig. 1, suppose that the velocity potential ϕ is given by $\phi = \phi_1 \cos pt$, where ϕ_1 is a function of x and y only. For ϕ_1 we must search for a plane harmonic

* See Lamb, *Hydrodynamics*, Cambridge University Press (1932), page 364.

WAVES IN AN OPEN OSCILLATING TANK.

Fig. 1.

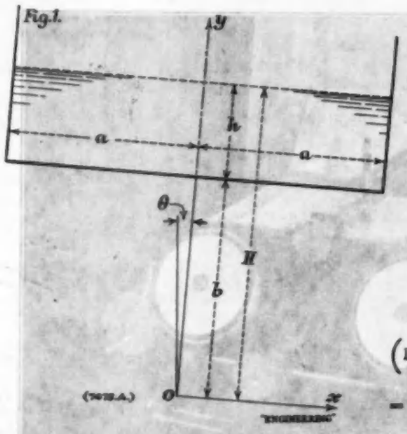
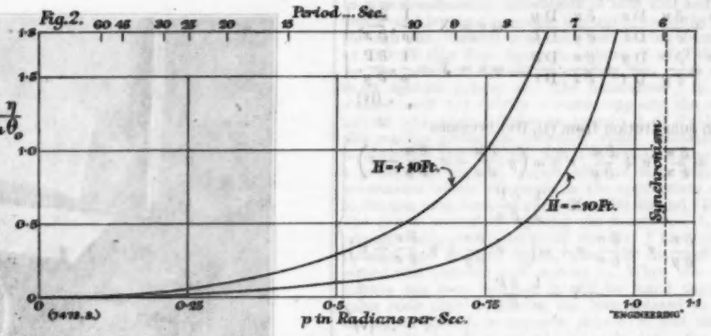


Fig. 2.



function satisfying the conditions :—

$$\frac{-\partial \phi_1}{\partial x} = \omega_0 y \text{ at } x = \pm a, \quad . \quad (2)$$

$$\frac{-\partial \phi_1}{\partial y} = -\omega_0 x \text{ at } y = b, \quad . \quad (3)$$

$$\frac{p^2 \phi_1}{g} = \frac{\partial \phi_1}{\partial y} \text{ at } y = H. \quad . \quad . \quad (4)$$

Equation (4) is the surface condition normally used with fixed axes, and the small error resulting from the rotation of the axes is discussed in the appendix, which is due to the late Dr. E. G. C. Poole.

Consider

$$\phi_1 = -\omega_0 xy + \Sigma A_m \sin mx \cosh m(y-b) + \Sigma B_m \sin mx \cosh m(H-y). \quad . \quad . \quad (5)$$

Then

$$\frac{\partial \phi_1}{\partial x} = -\omega_0 y + \Sigma A_m m \cos mx \cosh m(y-b) + \Sigma B_m m \cos mx \cosh m(H-y),$$

and (2) will be satisfied if

$$m = \frac{(2n+1)\pi}{2a}, \quad . \quad . \quad . \quad (6)$$

n being a positive integer, zero included.

Accordingly, at $y = b$,

$$\frac{\partial \phi_1}{\partial y} = -\omega_0 x - \sum_{n=0}^{\infty} B_{2n+1} \frac{(2n+1)\pi}{2a} \sin \frac{(2n+1)\pi x}{2a} \sinh \frac{(2n+1)\pi h}{2a},$$

so that to satisfy (3) we must make

$$-\sum_{n=0}^{\infty} B_{2n+1} \frac{(2n+1)\pi}{2a} \sin \frac{(2n+1)\pi x}{2a} \sinh \frac{(2n+1)\pi h}{2a} = 2\omega_0 x \quad . \quad . \quad . \quad (7)$$

over the range $a > x > -a$. It is therefore necessary to represent x over this range by a Fourier series of sines of odd multiples of $\frac{\pi x}{2a}$. This difficulty can be overcome by a device similar to that employed in the torsion problem for a rectangular bar.* It is known† that the Fourier series

$$\sum_{n=0}^{\infty} C_{2n+1} \sin \frac{(2n+1)\pi x}{2a},$$

$$\text{where } C_{2n+1} = \frac{8a(-)^n}{(2n+1)^2\pi^2}, \quad . \quad (8)$$

represents x when $a > x > -a$, $(2a - x)$ when $2a > x > a$, and $-(2a + x)$ when $-a > x > -2a$. It may be concluded that this series is satisfactory for the present purpose, and hence, from (7)

$$B_{2n+1} = \frac{-2\omega_0 C_{2n+1}}{\frac{(2n+1)\pi}{2a} \sinh \frac{(2n+1)\pi h}{2a}}. \quad (9)$$

It is then necessary to satisfy the surface condition. On substituting (5) and (6) in (4) we obtain

$$\left(1 - \frac{p^2 H}{g}\right) \omega_0 x + \frac{p^2}{g} \sum_{n=0}^{\infty} B_{2n+1} \sin \frac{(2n+1)\pi x}{2a} = -\sum_{n=0}^{\infty} A_{2n+1} \frac{(2n+1)\pi}{2a} \sin \frac{(2n+1)\pi x}{2a} \sinh \frac{(2n+1)\pi h}{2a} - \frac{p^2}{g} \sum_{n=0}^{\infty} A_{2n+1} \sin \frac{(2n+1)\pi x}{2a} \cosh \frac{(2n+1)\pi z}{2a},$$

and, when use is again made of (8), this becomes

$$A_{2n+1} = \frac{\left(1 - \frac{p^2 H}{g}\right) \omega_0 C_{2n+1} + \frac{p^2}{g} B_{2n+1}}{\frac{(2n+1)\pi}{2a} \sinh \frac{(2n+1)\pi h}{2a} - \frac{p^2}{g} \cosh \frac{(2n+1)\pi h}{2a}}. \quad . \quad . \quad (10)$$

The free oscillations defined in (1) may be divided into two classes, according as nodes or crests and hollows occur at the end walls. For the former, s is even and for the latter, odd. The "speeds" of the latter class are, therefore, given by

$$p^2_{2n+1} = \frac{(2n+1)\pi g}{2a} \tanh \frac{(2n+1)\pi h}{2a}, \quad (11)$$

where, as before, $n = 0, 1, 2 \ldots$ Then, with the aid of (9) and (11), (10) becomes

$$A_{2n+1} = \frac{C_{2n+1}\, \omega_0 \operatorname{sech} \frac{(2n+1)\pi h}{2a}}{p^2_{2n+1} - p^2} \left[g - p^2 H - \frac{2p^2 \operatorname{cosech} \frac{(2n+1)\pi h}{2a}}{\frac{(2n+1)\pi}{2a}} \right]. \quad (12)$$

Equations (6) and (11) show that the forced oscillations have the modes given by odd values only of s, and from (12) it appears that with these synchronism is possible.

Finally, we must obtain the elevation η of the waves at the end of the tank when the tank is in its extreme position, i.e., when $x = a$, $y = H$, $\cos pt = 0$. With these values of the variables,

$$\eta = \frac{1}{g} \frac{\partial \phi}{\partial t} = -\frac{p}{g} \left[-\omega_0 a H + \sum_{n=0}^{\infty} A_{2n+1} (-)^n \cosh \frac{(2n+1)\pi h}{2a} + \sum_{n=0}^{\infty} B_{2n+1} (-)^n \right],$$

which, on substitution from (8), (9), (11) and (12), reduces to

$$\eta = \frac{-p^2 \theta_0 a}{g} \left[-H + \frac{8}{\pi^2} \sum_{n=0}^{\infty} \frac{g - p^2 H - 2g \operatorname{sech} \frac{(2n+1)\pi h}{2a}}{\left(p^2_{2n+1} - p^2\right)(2n+1)^2} \right]. \quad (13)$$

On replacing H by $-H$ in (13) the elevation when the fixed axis O is above the tank is obtained. If O is displaced laterally relative to the tank, a variation in g results, but ship oscillations are comparatively slow and the effect on the waves is negligible.

It is of interest to check the analysis by applying it to the problem of oscillations in a tank moving in a horizontal straight line with velocity, say, $u_0 \cos pt$. H and b are now very great; ω_0 is zero but $\omega_0 H = u_0$. The origin may be transferred to the free surface, but the same analysis holds good. From (9), $B_{2n+1} = 0$ because $\omega_0 = 0$, and in (12) the only term inside the square brackets which remains is $p^2 H$. Thus,

$$A_{2n+1} = \frac{-C_{2n+1} p^2 u_0 \operatorname{sech} \frac{(2n+1)\pi h}{2a}}{p^2_{2n+1} - p^2}.$$

Then, from (5) and (8),

$$\phi_1 = -x u_0 + \sum_{n=0}^{\infty} A_{2n+1} \sin \frac{(2n+1)\pi x}{2a} \cosh \frac{(2n+1)\pi (y+h)}{2a},$$

where

$$A_{2n+1} = \frac{8a(-)^n}{(2n+1)^2\pi^2} \cdot \frac{u_0 \operatorname{sech} \frac{(2n+1)\pi h}{2a}}{1 - p^2_{2n+1}/p^2}.$$

This is in agreement with the result quoted by Milne-Thomson.*

Numerical Example.—Equation (13) has been evaluated for a tank of length 40 ft. ($a = 20$ ft.) and depth $h = 6$ ft. For H, the distance of the surface above the fixed axis, two values have been taken, of equal magnitude, 10 ft., but opposite in sign. The infinite series in (13) is rapidly convergent, and only the first term was of importance. The results are shown in Fig. 2, where the ratio $\frac{\eta}{a\,\theta_0}$ of the elevation of the waves at the ends to the vertical displacement of the ends is plotted against the "speed" p and the period of the disturbing oscillation. The gravest free mode, found by putting $s = 1$ in equation (1), is given by $p_1 = 1{\cdot}054$ radians per second, to which the corresponding period is 5·96 seconds. The curves in Fig. 2 are confined to the useful range where $p < p_1$. It will be seen that great advantages result from employing a negative value of H. However, the theory assumes that the motions are very small; how far it is correct for displacements of finite magnitude can only be determined by experiment.

The dimensions of swimming baths on large ships approximate to those of the tank under consideration, although the former are often of slightly varying depth. It may be remarked that the pitching period of these ships is about 8 seconds. When the disturbing oscillation is either nearly synchronous or very slow compared with the natural period of the bath, the position of the bath is of no consequence, but with the intermediate conditions under examination, the magnitude of the waves is very sensitive to the position of the bath, which should therefore be placed as low in the ship as possible.

Appendix on the Surface Condition (4).—We adopt axes rotating with the tank and employ Lamb's notation.† Then

$$\frac{Dx}{Dt} = u + \omega y, \quad \frac{Dy}{Dt} = v - \omega x, \quad . \quad (i)$$

$$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} = 0, \quad \frac{\partial u}{\partial y} - \frac{\partial v}{\partial x} = 0, \quad . \quad (ii)$$

* See Love, *Mathematical Theory of Elasticity*, Cambridge University Press (1927), page 317.

† See Byerly, *Fourier's Series and Spherical Harmonics*, Ginn, Boston, U.S.A. (1893), page 51.

* *Theoretical Hydrodynamics*, Macmillan (1938), page 398.

† *Loc. cit.* p. 12.

$$u = \frac{-\partial\phi}{\partial x}, v = \frac{-\partial\phi}{\partial y} \quad . \quad . \quad .

STATIGRAPH GRAPH-DRAWING MACHINE.

Fig. 2.

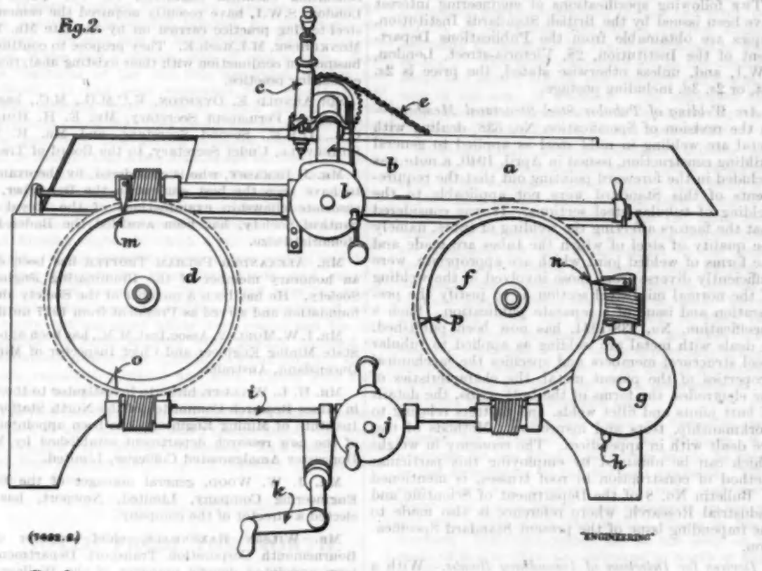


Fig. 3.

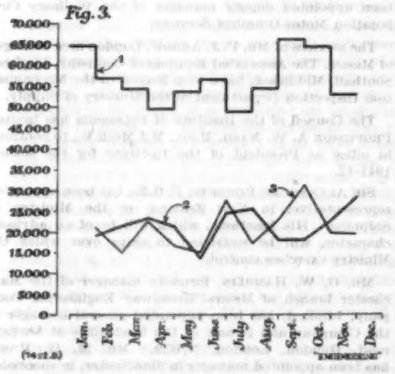
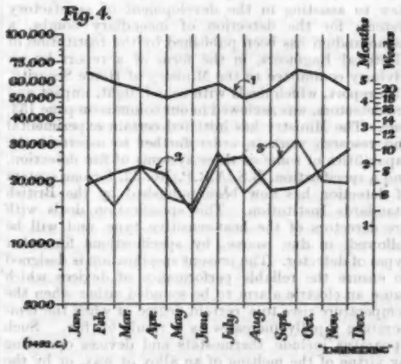


Fig. 4.



their relative trends. The use of this method, with the aid of a subsidiary percentage scale, enables the quotient of any two of the graphs to be measured correctly, thus providing information which an inspection of the figures arranged in columns would not yield.

Taking the arithmetical plotting shown in Fig. 3, having clamped the paper to the table, the first operation is to draw the vertical and base scale lines. The example given in this figure, as Table I shows, has its three graphs based on the amounts for twelve months, so that the base line has 12 equal spacings. A circular chart, selected from the range provided, and seen in the container in the lid in Fig. 1, is clamped to dial *f*. A suitable chart would be one with its periphery graduated in 60 divisions and this could be used either to illustrate monthly fluctuations over a period of five years, when the ordinates would be spaced 4 mm. apart, or for a period of one year, which would give ordinates with spacings of 20 mm. The vertical scale is next selected. This is set out from a circular chart clamped to dial *d*. The difficulty in selecting a scale which often occurs in hand-drawn graphs is reduced in the Statigraph by the provision of a series of charts having graduations ranging from 0 to 100 to 0 to 1,000, the last in steps of 100. This standard range will serve for most purposes, since the graduations can be given appropriate values at will, as shown in the examples described below. One complete revolution of the dial *d* gives a pen movement of 250 mm.

For the graphs shown in Fig. 3, the highest figure in column 1 of Table I shows that a chart having graduations of from 0 to 1,000 may be chosen for dial *d*, since the amounts to be plotted are large. Each graduation should be read as 100 for such an example, so that when plotting, say, the top figure of column 1 of Table I the reading on the dial would be 647·5. To construct the scales the table is set free from the pen by depressing lever *h* and is then traversed to the right by handwheel *g* until the pen is in line with the commencing point on the paper. The pen is then traversed by the handwheel *l* into the desired position for the point of origin and is brought into contact with the paper. It is then traversed across the paper to draw a vertical line, the movement being stopped when the figure 700 on the chart of dial *d* comes opposite the fixed pointer *m*, the chart having been clamped to the dial with its zero mark coincident with this point when the pen was at the origin. The scale is then graduated as required by making short forward and backward traverses of the table, the positions of the graduations being determined by the successive correspondence of the value chart divisions with the pointer. The graduation figures on the paper can be made in pencil for subsequent typing. A similar procedure is then followed to construct the horizontal base line, the graduations along which are determined by readings from the time chart on dial *f* as the selected divisions on that chart come into line with pointer *n*. Obviously, instead of indicating the several points on either scale by short projections, lines can be ruled right across the paper if desired.

The scales having been thus set out, the construction of the stepped graph, Fig. 3, is proceeded with on the assumption that the values in column 1, Table I, are taken at the end of each month. A horizontal line is drawn for the month of January by setting the pen to such a point, by handwheel *l*, that the value 647·5 on the scale chart of dial *d* comes opposite pointer *m*. The table is then moved to the left, through a space denoting one month, by the handwheel *g*, this distance being read off at the pointer *n* of the time scale chart on dial *f*. A vertical line is then drawn down to level 569·8 for February, this line being followed by a horizontal one to the end of the month. The processes are repeated for the whole graph, and it will be realised that they are wholly mechanical, all the plotting being determined by rotation of the two dials. The graphs in Fig. 3, representing the figures of columns 2 and 3, Table I, will obviously be so close together that a stepped form is unsuitable owing to the coincidence of the vertical lines. They are, therefore, plotted in straight-line form.

To construct these graphs the dial motions are coupled to give simultaneous movements of both dial and pen, and lever *h* is raised to couple the pen drive to the table through the variable gear, the pen having been set at 190·65 (the first figure in column 2 of Table I) by the previous method of reading the value scale chart against pointer *m*. The handwheel *j* is then rotated until the pointer *o* comes opposite the value 216·45 (the second figure in column 2 of Table I), this reading giving the February value. Rotation of handwheel *j* also sets the infinitely-variable gear into a position giving the correct ratio of table and pen movements which will result in the appropriate slope to the pen path between the points 190·65 and 216·45. The pen is moved by turning the handwheel *k*, this turning being continued until the dial *f* has rotated through one monthly space, when the division concerned will coincide with pointer *n*. When this coincidence has been reached, it will be found that the value scale chart on dial *d* has been rotated so that the figure 216·45 is opposite pointer *m* and that a sloping line has been traced across the space for February. The pointer *o* is then turned by handwheel *j* to the next figure in the table, viz., 233·7, and the handwheel *k* is once more rotated to turn dial *f* through another division of the time scale. Successive repetitions of these two movements completes the graph and it will be appreciated that, here again, the operation is a purely mechanical one. The graph for column 3 of Table I is drawn in the same way as that for column 2, though a different size of pen or ink of a different colour may be used to distinguish the two more clearly.

It may be noted here that if pointer *o* is rotated into coincidence with pointer *m* the resultant line will be horizontal, since the gear between the pen and table drives will be in its zero position. This condition occurs when two exactly equal amounts follow one another. The gear consists of a horizontal circular disc with a horizontal roller situated diametrically above it. Between the disc and the roller are a pair of steel balls placed one above the other and held thus in a cage. The cage is traversed radially relative to the disc by a lead screw actuated by the handwheel *j*. When the disc is rotated by the handwheel *k*, which is effected through bevel gears, the balls also rotate and cause the roller to rotate. The speed of rotation of the roller naturally depends on the radial distance of the balls from the centre of the disc, this centre being the zero point just refegred to. Movement of the balls across the centre of the disc from the position previously occupied reverses the direction of rotation of the roller and the direction of slope of the line being drawn. When the lever *k* is raised in order to engage the gear, this movement gears the lead screw, which gives motion to the table, to the spindle of the disc, the lead screw thread being chosen so that it gives the correct ratio of movement between the table and the pen and between both of these and the respective dials. Since pure rolling action is obtained by the use of the two balls, only negligible effort is necessary either to set the gear or to rotate the disc, while there is sufficient pressure between roller, balls and disc to eliminate any slipping. This is a feature of considerable importance when changes of value are slight and the balls are correspondingly close to the centre of the disc. It is stated that slip does not occur even if the balls are slightly oiled.

The graphs shown in Fig. 4 are drawn from the same series of figures as given in Table I and as drawn arithmetically in Fig. 3. The arithmetically-graduated chart on dial *d*, however, is replaced by one graduated logarithmically, in two cycles; that is, the logarithmic graduation extends round half the periphery of the chart and is then repeated. The chart is first placed on dial *d* with the minimum figure of the series coincident with pointer *m*, in order to see where the maximum figure will come on the paper, and then, if this appears to be too low down, the value line is continued upwards for a suitable distance and the value scale chart is re-set with its figure 7 coincident with pointer *m* to denote 70,000. Scale graduations are made down the line by watching the value scale chart in relation to the fixed pointer and drawing short horizontal lines at its major graduations. The pen is then moved up, for the start of the graph of the figures of column 1 of the table, to the 6·475 level at the end of January, the logarithmic scale being, of course, graduated from 1 to 10. Thereafter, the method of drawing the graphs is the same as has already been described for the arithmetical graphs, the logarithmic value scale chart automatically placing the various points.

The double scale at the right hand of Fig. 4 illustrates a way in which the Statigraph can be employed to give new information. It is set out from the same value scale chart as the scale on the left-hand, but is obviously started from a different point in the scale. The first two columns of figures in Table I may represent, say, trade debts at the end of the month in

column 1 and graph 1, and receipts during the month in column 2 and graph 2. The vertical distance between these two graphs represents the ratio of receipts to outstanding debts, and by measuring the distances on the right-hand scale the average monthly credit allowed can be ascertained. A weekly scale can be added by placing the pen on the three-month graduation and then rotating the value-scale chart to 13 the number of weeks in the quarter-year, thereafter marking the weekly graduations.

Space does not permit us to give other examples of the uses of subsidiary scales to provide, automatically, direct measurements of any quotient desired, but a few notes on the general employment of the semi-log, or ratio scale, graph may be made. When, for instance, it is required to compare two series of figures which are almost, but not quite, identical in value and trend, independent scales may be drawn, since the figures may be in different units of measurement; for instance, one may be in tons and the other in pounds sterling. An arithmetical scale is likely to be misleading in such a case and would be useless for the comparison of many different factors. Statistical services, therefore, make wide use of ratio scales but printed semi-log paper involves the plotting of the graphs in almost the same position, so that confusing intersections result. With the un-ruled paper of the Statigraph, however, the graphs can be effectively separated vertically, an independent scale being constructed for each. Graphs of this kind are published from time to time, showing, for example, the industrial share index of the United Kingdom against the production of pig iron, on a percentage basis, or the Dow-Jones average of industrial shares, widely used in the United States, against the spelter stocks in that country.

A further advantage of the Statigraph is that either arithmetical or geometrical moving average curves can be drawn, without calculation, subsidiary scales of smaller diameter than the normal being employed. These are arranged on the dial above the main scales, over which they are free to rotate relatively, the subsidiary scale being used in a manner analogous to the manipulation of a slide rule. Meanwhile, the original value-scale chart, which is clamped to the dial, indicates the actual value of the average at each point. The Statigraph can be used for drawing graphs of engine and machinery tests at the job, as the paper does not require to be handled and is, therefore, not exposed to oil and dust. The only limitation to this use is that the intervals along the time base must be equal. The instrument can also be used as a ruling machine for setting out unusual office forms, and close approximations of calculations normally carried out on a slide rule can be obtained. As regards the degree of accuracy obtainable with the instrument, the charts have a graduated circumference of 15 in., which provides a degree of accuracy 50 per cent. greater than that obtained by hand plotting on a chart 10 in. high. As the mechanical drives to the scale dials are on opposite sides of the driving member, the only backlash apparent is the difference between two other backlashes. This arrangement gives great accuracy of indication and the use of bevel gearing enables backlash to be adjusted on either side of the driving member. The only components vital to accuracy are those comprising the infinitely-variable gear, which, it is stated, has not been affected by hard usage for over 18 months. The Statigraph has been designed and patented by Mr. R. A. Mills, 1, Richmond-road, Wakefield, and the first example, illustrated in Fig. 1, was constructed by Messrs. Negretti and Zambra, 38, Holborn-viaduct, London, E.C.1.

ROYAL AERONAUTICAL SOCIETY.—New regulations and syllabuses for the associate-fellowship examinations of the Royal Aeronautical Society have been prepared. We are informed that they will come into force at the examination to be held in May, 1943. Until that date the examinations will be held under the existing syllabuses.

THE LATE MR. F. A. HOGG.—Shipowners and shipbuilders in all parts of the country will learn with regret of the sudden death of Mr. Frank A. Hogg, which occurred on March 6 while he was travelling from his home in Essex to his office in the City. Mr. Hogg was joint secretary of the Chamber of Shipping of the United Kingdom, the staff of which he joined some 25 years ago. After serving as chief clerk for upwards of 20 years, he was made joint secretary last summer. He was also secretary of the Tramp Shipping Administrative Committee of the Chamber, since its formation in 1935. Mr. Hogg was a great worker and a zealous and loyal servant of the Chamber. He will long be remembered among shipping men for his efficient work in the arrangement and organisation of the annual meeting, annual dinner, and other important functions of the Chamber. He was only 52 years of age.

BRITISH STANDARD SPECIFICATIONS.

THE following specifications of engineering interest have been issued by the British Standards Institution. Copies are obtainable from the Publications Department of the Institution, 28, Victoria-street, London, S.W.1, and, unless otherwise stated, the price is 2*s.* net, or 2*s.* 3*d.* including postage.

Arc Welding of Tubular Steel Structural Members.—In the revision of Specification No. 538, dealing with metal arc welding in mild steel as applied to general building construction, issued in April, 1940, a note was included in the foreword pointing out that the requirements of this Standard were not applicable to the welding of tubular steel sections. It was considered that the factors affecting the welding of tubes, namely the quality of steel of which the tubes are made and the forms of welded joint which are appropriate, were sufficiently diverse from those involved in the welding of the normal mild-steel section as to justify the preparation and issue of a separate publication. Such a specification, No. 938-1941, has now been published. It deals with metal arc welding as applied to tubular steel structural members and specifies the mechanical properties of the parent metal, the characteristics of the electrodes, the forms of the butt welds, the details of butt joints and fillet welds, and matters relating to workmanship, tests and inspection. Methods of test are dealt with in appendices. The economy in weight which can be obtained by employing this particular method of construction in roof trusses, is mentioned in Bulletin No. 8 of the Department of Scientific and Industrial Research, where reference is also made to the impending issue of the present Standard Specification.

Devices for Detection of Incendiary Bombs.—With a view to assisting in the development of satisfactory systems for the detection of incendiary bombs, a memorandum has been published by the Institution of Electrical Engineers, in the form of a report by an advisory committee to the Ministry of Home Security. This report, which deals with sound, light, impact and fire detectors, was reviewed in our columns on page 153, *ante*. The Ministry has initiated certain experimental and research work in order further to ascertain the capabilities of some of these systems of fire detection, and a specification, B.S./A.R.P. No. 53, for one system of detection has now been published by the British Standards Institution. This specification deals with fire detectors of the heat-sensitive type, and will be followed, in due course, by specifications for other types of detector. The present specification is designed to ensure the reliable performance of devices which cause an electric alarm to be sounded either when the temperature rises to a certain degree or when the temperature rapidly increases as a result of fire. Such apparatus include thermostats and devices operating by virtue of the melting of an alloy or wax, or by the expansion of a liquid. The method of testing the detector is defined and notes are given on the selection, installation and maintenance of detection systems. [Price 4*d.*, including postage.]

BOOKS RECEIVED.

Egypt. Ministry of Public Works. Physical Department. Paper No. 40. *The Suspended Matter in the Nile. Report on Investigations Relating to the Aswan Reservoir.* By Y. M. SIMAIKA. Cairo: Publications Office, Government Press. [Price P.T.20, or 4*s.*]

Cement Chemists' and Works Managers' Handbook. By W. WATSON and Q. L. CRADDOCK. London: Concrete Publications, Limited, 14, Dartmouth-street, S.W.1. [Price 15*s.* net.]

Reinforced Concrete Chimneys. By C. P. TAYLOR and LESLIE TURNER. London: Concrete Publications, Limited, 14, Dartmouth-street, S.W.1. [Price 8*s.* 6*d.* net.]

United States Bureau of Labor Statistics. Serial No. R.1164. *Injury Experience in the Iron and Steel Industry, 1938 and 1939.* By G. R. MCCORMACK, under the direction of SWEN KJAER. Washington: Superintendent of Documents.

The High-Speed Internal-Combustion Engine. By H. R. RICARDO. Third edition, revised by H. S. GLYDE. London: Blackie and Son, Limited. [Price 30*s.* net.]

United States War Department. Port Series No. 9 (Revised 1940.) *The Port of Charleston, S.C.* [Price 60 cents.] Port Series No. 10. (Revised 1940.) *The Ports of Savannah and Brunswick, Ga.* [Price 55 cents.] Port Series No. 14. (Revised 1940.) *The Ports of Port Arthur, Sabine, Beaumont and Orange, Texas.* [Price 60 cents.] Port Series No. 32. (Revised 1940.) *The Ports of Astoria, Oreg., and Longview and Vancouver, Wash.* [Price 75 cents.] Port Series No. 33. (Revised 1940.) *The Port of Wilmington, N.C.* [Price 35 cents.] Washington: Superintendent of Documents.

PERSONAL.

MESSRS. E. F. MACTAGGART and W. EDMUND EVANS, consulting chemical engineers, 14, Old Queen-street, London, S.W.1, have recently acquired the cement and steel-testing practice carried on by the late MR. E. W. MONKHOUSE, M.I.Mech.E. They propose to continue the business in conjunction with their existing analytical and consulting practice.

SIR ARNOLD E. OVERTON, K.C.M.G., M.C., has been appointed Permanent Secretary, MR. E. H. HODGSON, C.B., O.B.E., Second Secretary, and MR. R. C. G. SOMERVELL, Under Secretary, to the Board of Trade.

MR. J. BEKASSY, who is considered, by the examiners, to have been the best student in the December, 1940, associate-fellowship examinations of the Royal Aeronautical Society, has been awarded the Baden-Powell Memorial Prize.

MR. ALEXANDER PELHAM TROTTER has been elected an honorary member of the Illuminating Engineering Society. He has been a member of the Society since its foundation and served as President from 1917 until 1921.

MR. I. W. MORLEY, Assoc.Inst.M.M., has been appointed State Mining Engineer and Chief Inspector of Mines for Queensland, Australia.

MR. H. L. WILLETT, hitherto investigator to the Safety in Mines Research Committee of the North Staffordshire Institute of Mining Engineers, has been appointed head of the new research department established by Messrs. Doncaster Amalgamated Collieries, Limited.

MR. J. W. WOOD, general manager of the Uskside Engineering Company, Limited, Newport, has been elected a director of the company.

MR. WILSON BAXENDALE, chief engineer of the Bournemouth Corporation Transport Department, has been appointed deputy manager of the Wallasey Corporation Motor-Omnibus Services.

The services of MR. P. J. ARROW, London area manager of Messrs. The Associated Equipment Company, Limited, Southall, Middlesex, have been loaned to the Mechanisation Inspection Department of the Ministry of Supply.

The Council of the Institute of Petroleum has invited PROFESSOR A. W. NASH, M.Sc., M.I.Mech.E., to continue in office as President of the Institute for the session 1941-42.

SIR ALEXANDER ROBERTS, K.B.E., has been appointed representative, in New Zealand, of the Ministry of Shipping. His functions, which will be of an advisory character, will be restricted to ships over which the Ministry exercises control.

MR. G. W. HAMBLIN, formerly manager of the Manchester branch of Messrs. Broadway Engineering Company, Limited, has been appointed general manager to the Company and is now at the head office at Carlisle-road, Hendon, London, N.W.9. MR. M. H. ROBIN has been appointed manager in Manchester, in succession to Mr. Hamblin, and MR. J. B. RITCHIE has been appointed manager in Glasgow.

UNITED STATES COLLIERY INDUSTRY.—It is reported that the production of bituminous coal in the United States during the week ended January 18 averaged 1,633,000 tons daily, against 1,683,000 tons in the preceding week and 1,655,000 tons in the corresponding week of 1940.

INSTITUTION OF AUTOMOBILE ENGINEERS.—It is hoped to make arrangements for the examinations of the Institution of Automobile Engineers to be conducted in London and such other centres—at home and overseas—as may be required, on Thursday, May 8. Probationary graduates who are eligible to sit for the examination and who desire to do so, should inform the Secretary at 12, Hobart-place, London, S.W.1, to that effect in order that the necessary arrangements may be made. The entry list will close on April 19.

RECENT TECHNICAL BOOKS.—In spite of the difficult conditions prevailing, the Association of Special Libraries and Information Bureaux is continuing the issue of its valuable *Aslib Book-List*. This publication, which appears quarterly, contains particulars of recent scientific and technical books arranged under some 40 headings. These naturally cover some subjects outside the range of this journal, but considerably more than half of the sections are of direct engineering interest. The selection under each heading is made by some specialist body concerned with the particular subject, so that users may feel assured that the selection made from recent publications is a sound one. The first issue of this year contains 165 entries. The *Aslib Book-List* may be obtained from the offices of Aslib, 31, Museum-street, London, W.C.1, for 10*s.* 6*d.* per annum, post free. It is supplied to full members of Aslib without charge.

NOTES FROM THE SOUTH-WEST.

CARDIFF, Wednesday.

The Welsh Coal Trade.—A statement on the position of Egypt as a customer for South Wales coal, made by Dr. Hassan Nashaat Pasha, the Egyptian Ambassador, has aroused considerable interest on the steam-coal market. He said that in normal times Egypt imported from Wales half a million tons of coal a year. Since the beginning of the war this important market had suffered. It had been suggested that Egypt should obtain supplies from India or South Africa, but the Egyptians found that they could not do without Welsh coal and were now getting supplies from Wales. It will be recalled that a few months ago the Egyptian State Railways made representations to the British authorities to obtain facilities for the maintenance of supplies. Export business, last week, remained limited, being almost exclusively for the Portuguese, South American and Eireann trades, in which a fair activity was maintained. Home demand, however, was active, especially for the high-volatile bituminous kinds, and supplies were difficult to secure. Dry steams were in steady demand. Best large descriptions were moving off satisfactorily but the sized kinds were scarce and the lots available for early delivery were quickly disposed of. Bituminous smalls were difficult to stem, but dry steam smalls remained plentiful and dull. Cokes were busy and firm, but patent fuel was slow.

The Iron and Steel Trade.—There was a steady demand in the iron and steel and allied trades during the week, but supplies were not easy to secure. As a result, works were kept engaged almost to full capacity, and the tone was very firm.

NOTES FROM THE NORTH.

GLASGOW, Wednesday.

Scottish Steel Trade.—Active conditions are still general in the Scottish steel trade and production is being maintained at a high level as the supply of raw material has been ample for the requirements of the industry. The demands for all kinds of material are very heavy. Shipbuilders, in particular, are using a large tonnage of plates, and the steelmakers are so busy that the delivery date for new orders is about three months. For boiler plates, the conditions are very similar and the demand for light steel is on a large scale. In the black and steel-sheet trade, various Government schemes are accounting for the greater part of the current output. The current quotations are as follows:—Boiler plates, 17*l.* 12*s.* 6*d.* per ton; ship plates, 16*l.* 3*s.* per ton; sections, 15*l.* 8*s.* per ton; medium plates, ¼ in. and thicker, rolled in sheet mills, 21*l.* 15*s.* per ton; black-steel sheets, No. 24 gauge, 22*l.* 15*s.* per ton; and galvanised corrugated sheets, No. 24 gauge, 26*l.* 2*s.* 6*d.* per ton, all for home delivery.

Malleable-Iron Trade.—The West of Scotland malleable-iron makers are fully occupied. The recent increase in demand is being well met and busy conditions are likely to be general for some time as consumers have many Government contracts on hand. The re-rollers of steel bars are also fully employed on urgent orders and as supplies of semies are adequate, plant is being kept running at full capacity. The following are the current quotations:—Crown bars, 15*l.* 12*s.* 6*d.* per ton; No. 3 bars, 13*l.* 12*s.* 6*d.* per ton; No. 4 bars, 13*l.* 17*s.* 6*d.* per ton; and re-rolled steel bars, 17*l.* 15*s.* per ton, all for home delivery.

Scottish Pig-Iron Trade.—There has been no change in the state of the Scottish pig-iron trade during the week, and makers are having to meet a pressing demand for both hematite and basic iron. The demand for foundry grades has improved considerably and a further expansion in the near future is probable. The market quotations are as follows:—Hematite, 6*l.* 18*s.* 6*d.* per ton, and basic iron, 6*l.* 0*s.* 6*d.* per ton, both delivered at the steel works; foundry iron, No. 1, 6*l.* 5*s.* 6*d.* per ton, and No. 3, 6*l.* 3*s.* per ton, both on trucks at makers' yards.

ANDREW CARNEGIE RESEARCH GRANTS.—The Council of the Iron and Steel Institute awards annually Andrew Carnegie Scholarships, usually to the value of 50*l.* or 100*l.*, in order to assist those employed in research, irrespective of sex or nationality. Candidates must be under 35 years of age and the proposed subject of research should be of interest to the iron and steel industry. Applications should be made on forms obtainable from the Secretary of the Institute, 4, Grosvenor-gardens, London, S.W.1. Completed forms should be submitted not later than May 31 or September 30 in each year. The results of researches in respect of these awards must be communicated to the Iron and Steel Institute in the form of a report for publication, and the Andrew Carnegie Gold or Silver Medal may be awarded to the author of the report which, in the opinion of the Council, is the most meritorious of the year.

NOTES FROM CLEVELAND AND THE NORTHERN COUNTIES.

MIDDLESBROUGH, Wednesday.

General Situation.—The existing conditions are still restricting market operations in iron and steel, but the system of controlled distribution ensures satisfactory deliveries of materials for the requirements of war contractors. The usual customers are in the market with home and export orders, but ordinary commercial business is not easy to transact. The aggregate tonnage output is still at nearly a record level and imports from the United States have expanded appreciably.

Cleveland Iron Trade.—Increased activity at the foundries involves a heavier consumption of pig iron in spite of the extensive use of scrap. Only small parcels of Cleveland pig are obtainable and there seems to be no likelihood of material addition to the light irregular make. Deliveries from other producing centres, however, are adequate for the requirements of the founders. Midland iron is passing into use for most purposes, and for particular specified needs adequate parcels from Scotland and elsewhere are coming to hand. Merchants are dealing with the requirements of their regular customers more satisfactorily than has been the case recently, but would be glad of the opportunity of handling considerably larger parcels. The official quotations for Cleveland pig are ruled by No. 3 description at 128*s.*, delivered within the Tees-side zone.

Hematite.—The limited make of hematite, supplemented by imports of American products, is just adequate for the demand, and care has to be exercised in the distribution of the tonnage available. There is every likelihood, however, of an early improvement. There is a possibility of some expansion in the make, and the supply from the United States is likely to increase. Stabilised values are at the level of No. 1 grade of iron at 133*s.* 6*d.*, delivered to North of England areas.

Basic Iron.—Basic iron is not on sale, but production is maintained at a rate that is adequate for the requirements of the makers' own steelworks. The small occasional surplus output is being retained. The nominal price of basic iron remains at 120*s.* 6*d.*

Foreign Ore.—Stocks of foreign ore are not large, but imports are coming in regularly and the extensive use of native ores has considerably reduced the dependency on the supply of ore from abroad.

Blast-Furnace Coke.—There is but little business in Durham blast-furnace coke. Local users have covered their requirements for considerable periods ahead and sellers do not wish to dispose of more of their large holdings until they have reduced their delivery obligations appreciably. Fixed prices are based on good medium qualities at 35*s.* 6*d.* f.o.r.

Manufactured Iron and Steel.—The ample supply of semi-finished iron and steel is keeping re-rolling plant operating at full capacity. The total output of finished commodities is promptly passing into use, as also is the supply from overseas. A more rigid exclusion of orders for ordinary commercial purposes is enabling better deliveries of material to be made for essential requirements. The call for yet larger supplies of shipbuilding requisites is still persistent, and the demand for black and galvanised sheets is unabated; railway material is also in considerable request. Soft steel billets are quoted at 12*l.* 5*s.*; hard billets at 13*l.* 12*s.* 6*d.*; joists and sections at 15*l.* 8*s.*; heavy plates at 16*l.* 3*s.*; and heavy rails at 14*l.* 10*s.* 6*d.*

Scrap.—The scrap market is active. Users of all grades of steel are anxious to place extensive orders.

TROOP SPECIAL TRAINS ON THE L.M.S.—Since the commencement of the war, the London Midland and Scottish Railway has run 10,512 special trains, conveying 86,303 officers and 2,960,142 men of the fighting forces.

LEAFLETS ON ENGINEERING WAR WORK.—The Ministry of Labour and National Service has issued publicity leaflets entitled "Going Away on War Work" (P.L. 83), and "Engineering Training for Women" (P.L. 84). The first (P.L. 83) contains a special foreword by the Minister of Labour and National Service, and provides answers to some of the questions likely to be asked by people who are leaving their homes to take up war work in other areas. Points covered in the leaflet relate to the journey and to lodgings, and include the consideration of such questions as meals, and recreation and medical facilities. In the second leaflet (P.L. 84) women are told how to apply for training, what types of courses are available, and how long training takes. The leaflet also briefly describes what engineering work is like and deals with such questions as training allowances and training away from home. Copies of the leaflets may be obtained from any Employment Exchange or direct from the Ministry of Labour and National Service (Public Relations Branch), Montagu House, Whitehall, London, S.W.1.

NOTICES OF MEETINGS.

It is requested that particulars for insertion in this column shall reach the Editor not later than Tuesday morning in the week preceding the date of the meeting.

INSTITUTION OF MECHANICAL ENGINEERS.—To-day, 2.30 p.m., Storey's-gate, St. James's Park, S.W.1. General Meeting. Informal Discussion on "Munitions Labour Supply Organisation," to be opened by Mr. W. H. Denholm.

JUNIOR INSTITUTION OF ENGINEERS.—Saturday, March 22, 2 p.m., 39, Victoria-street, Westminster, S.W.1. Ordinary Meeting. "The Chemist, The Chemical Engineer and the Mechanical Engineer," by Mr. P. A. Cartwright.

MANCHESTER ASSOCIATION OF ENGINEERS.—Saturday, March 22, 2.15 p.m., The Engineers' Club, Albert-square, Manchester. Annual General Meeting. "Planning and Organisation for War-Time Management," by Messrs. F. C. Lawrence and C. J. W. Cole.

INSTITUTION OF CIVIL ENGINEERS.—*Yorkshire Association:* Saturday, March 22, 2.30 p.m., The Hotel Metropole, King-street, Leeds. Ordinary Meeting. "Some Applications of Structural Geology," by Dr. H. C. Versey.

INSTITUTION OF ELECTRICAL ENGINEERS.—*North-Western Centre:* Saturday, March 22, 2.30 p.m., The Engineers' Club, Albert-square, Manchester. Joint Meeting with THE INSTITUTION OF POST OFFICE ELECTRICAL ENGINEERS. "Some Aspects of Line Construction," by Mr. R. M. Chamney. *North-Eastern Centre:* Monday, March 24, 6.15 p.m., The Neville Hall, Westgate-road, Newcastle-upon-Tyne. Informal Meeting. "A.R.P. in the Electrical Industry," by Mr. R. H. Brierly. *North-Western Students' Section:* Tuesday, March 25, 6 p.m., The Engineers' Club, Albert-square, Manchester. "Problems Evening."

ROYAL SOCIETY OF ARTS.—Wednesday, March 26, 1.45 p.m., John Adam-street, Adelphi, W.C.2. The Aldred Lecture: "Discovery and Invention," by Sir Richard Gregory, F.R.S.

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.—*Student Section:* Wednesday, March 26, 6.45 p.m., Bolbec Hall, Newcastle-upon-Tyne, 1. "Recent Development of Boilers," by Mr. A. Gilchrist. *Institution:* Friday, March 28, 6 p.m., The Mining Institute, Newcastle-upon-Tyne, 1. "The Economics of the Design of Condenser Plant and Water-Cooling Systems, Applicable to Power Stations," by Mr. W. T. Bottomley.

NOTES FROM SOUTH YORKSHIRE.

SHEFFIELD, Wednesday.

Iron and Steel.—Increased outputs are reported by the steel and engineering firms now primarily employed on war work. The labour position has improved; more men are being trained by the Ministry of Labour, and also by Sheffield University and Sheffield Education Committee. The position of the raw and semi-finished steel branches is highly satisfactory. The demand for basic billets continues to expand, and the consumption of acid steel has increased steadily during the past few months. Structural engineers are taking larger tonnages of steel. The demand for forge and foundry iron has been well maintained. Rolling mills, forges, foundries, wire and rod mills and heavy machine shops are all operating at full capacity. The heavy machinery and engineering trades report progress, and those producing railway rolling stock, such as springs, tyres, wheels, and engine parts, are booking an increased volume of business. Overseas requirements are not heavy, judged by pre-war standards. Activity in steelworks' and ironworks' machinery and related equipment is fully maintained. Makers of spring steel, agricultural steels, mining steels, deep-drawing steel, edge-tool steels, aircraft steels, composite steel, and alloy steels are accounting for record outputs. There is an active market in bright-drawn and cold-rolled mild steel, crucible cast steel, case-hardening steel, and stainless and rustless varieties. Electrical equipment is in better demand on inland account, and the call for grinding and crushing machinery shows a further improvement.

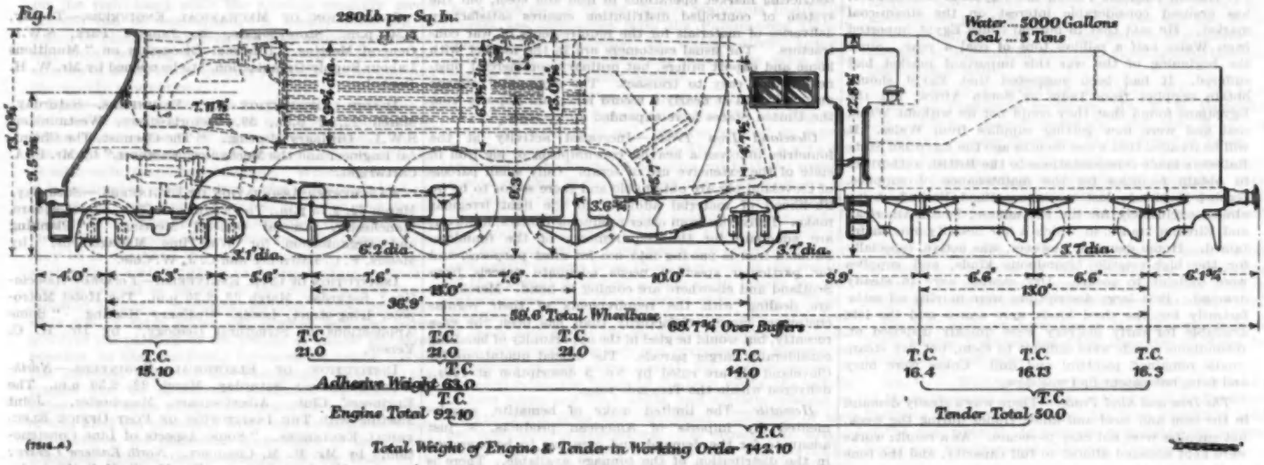
South Yorkshire Coal Trade.—The export position has undergone little change; the inland demand is brisk and covers a large variety of fuels. Industrial coal is being sent in large quantities to works in various parts of the country, and locomotive coal is in better demand. Steams are more active, and the house-coal market is still busy. There is an improved trade in all classes of cokes.

WINDING-ENGINE EXPORT GROUP.—Mr. I. V. Robinson has been elected chairman of the Winding-Engine Export Group. A secretary has not yet been appointed, but the offices of the Group are at 36, Kingsway, London, W.C.2.

4-6-2 TYPE STREAMLINED LOCOMOTIVE FOR THE SOUTHERN RAILWAY.

MR. O. V. BULLEID, M.I.MECH.E., CHIEF MECHANICAL ENGINEER.

Fig. 1.



4-6-2 TYPE STREAMLINED LOCOMOTIVE FOR THE SOUTHERN RAILWAY.

THE 4-6-2 type streamlined, or "air-smoothed," express locomotive, illustrated in Figs. 1 and 2, is the first of a class of three-cylinder simple expansion high-pressure engines, which are being built in the Eastleigh shops of the Southern Railway to the designs of the company's chief mechanical engineer, Mr. O. V. Bulleid, M.I.Mech.E. The new engines will comprise what is to be known as the Merchant Navy class and the first has been given the name of Channel Packet. The explanation for this somewhat unusual nomenclature is that at the outbreak of war the Southern Railway owned 42 vessels and, through its connection with Southampton and other ports, had many affiliations with the Merchant Navy. Since hostilities began, the company has had 34 of its ships chartered by the Government, and of these 14 were commissioned in the Naval service. Three of the ships were lost at Dunkerque and three more were sunk by the enemy at Dieppe.

The total weight of the engine and tender is 142 tons 10 cwt., of which the engine accounts for 92 tons 10 cwt. The height from rail level is 13 ft. 0⅛ in. and the length over the buffers is 69 ft. 7¾ in., the total wheel base being 59 ft. 6 in., and the coupled wheel base 15 ft. The driving wheels are 6 ft. 2 in. in diameter, and the diameters of the wheels of the leading and trailing bogies are 3 ft. 1 in. and 3 ft. 7 in., respectively. The tractive effort is 37,500 lb. The casing enclosing the engine is fabricated from rolled sections and $\frac{1}{16}$-in. steel plating, and is carried on the main frame instead of, as is usual, on the boiler. The latter is consequently free to expand inside the casing. The cab is a continuation of the "air-smoothed" casing and, like it, is carried on the frame. Forward of the smokebox-door plate the casing acts as an air collector and the large opening over the smokebox door forms the mouth of a funnel which tapers to a narrow slot in front of the chimney and discharges a stream of air upwards at high velocity. This stream acts as a distributor for the exhaust, which, owing to the multiple-jet blast pipe, is comparatively soft. The enclosed space between the frames in front of the smokebox is used to house a small turbo-generator set for supplying current for lighting. It is claimed that this is the first English steam locomotive to be completely lighted by electricity, this system being used both for the head and tail lights as well as for the gauge and inspection lamps. Two mechanical lubricator pumps are housed in the same enclosed space as the generator.

Turning to the steam-raising arrangements, the firebox, which has a grate area of 48·5 sq. ft. and a volume of 300 cub. ft., has both the inner and outer portions welded. An interesting feature is that the internal portion is of steel and is fitted with two Nicholson thermic syphons. Automatic fire-hole doors are also provided. The maximum external diameter of the boiler, which is lagged with spun glass mattresses, is 6 ft. 3½ in., and it tapers to 5 ft. 9½ in. at the front. The length between the tube plates is 17 ft. and the height of the centre from the rails is 9 ft. $5\frac{7}{16}$ in. The heating surface of the firebox, including the syphons, is 275 sq. ft., that of the tubes 1,241·6 sq. ft., and of the flues 934·3 sq. ft., giving a total of 2,450·9 sq. ft., to which must be added 822 sq. ft. of superheating surface. The working pressure is 280 lb. per square inch, which is understood to be the highest yet adopted in this country for an orthodox locomotive boiler. The three safety valves are set at an angle on the first ring of the boiler, instead of in the more usual position over the firebox.

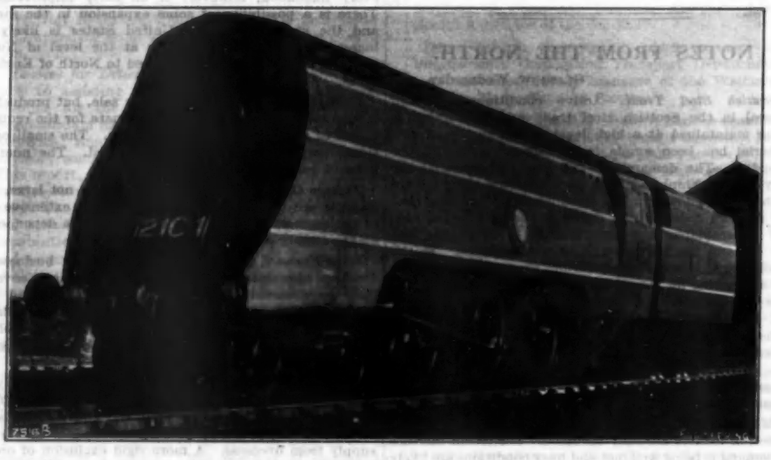


FIG. 2.

Each of the cylinders is 18 in. in diameter, the piston stroke being 24 in., which is a reversion to earlier practice, while the piston valves, which are 11 in. in diameter, are unusually large. These valves have a maximum travel of 6½ in. and a maximum cut-off of 70 per cent. They are actuated by Bulleid patent radial valve gears, in which the primary drive is provided by chain of the Morse pattern. The three sets of valves are enclosed in an oil-tight casing inside the frame. All the bearings within this casing are lubricated by a continuous stream of oil, which is distributed by gear pumps. All three connecting rods drive on the middle pair of coupled wheels and to allow this to be done the inside cylinder has had to be placed at an angle of 1 in 7·75, the inclination of the outside cylinders being 1 in 40. As will be noticed from the illustrations, double disc cast-steel wheel centres have been adopted both for the engine and the tender. These are of the B.F.B. type, in which the balance weights are disposed between the two discs. The coupled wheels are fitted with clasp brakes, each wheel having a brake block on both sides. The brakes are operated by four 21-in. cylinders, through automatic slack adjusters.

The cab and fittings are conveniently laid out, both injectors being fitted on the fireman's side while the steam and water controls are arranged in one group on the driver's side. The reversing gear is power-operated, the steam and hydraulic cylinders being controlled by a single lever. The tender, which has a capacity of 5,000 gallons, is carried on six wheels 3 ft. 7 in. in diameter and, as in the case of the engine, welding was largely used in its construction. The tender is filled through covers in the tender cab on each side, so that the work of the fireman is facilitated.

As previously mentioned, the new engines will be known as the Merchant Navy class, and the first of the series, the Channel Packet, bears the Southern Railway house flag in the centre of the nameplate. The remaining nine engines will be named Union Castle, Royal Mail, Cunard-White Star, Canadian Pacific, P. and O., Aberdeen and Commonwealth, Orient, Shaw Savill, and Blue Star. In place of the usual numbering system, these engines have a combination of letters and numbers which incorporates axle notation on a variation of the Continental system. Thus, the first locomotive, as shown in Fig. 2, carries the marking 21C 1, the number after the capital letter being that of the engine in the class. The first number refers to the two axles of the bogies and the second to the trailing axle. C is the Continental method of designating three coupled axles.

HALESWORTH AND SOUTHWOLD RAILWAY.—We are informed that the rolling stock of the derelict Halesworth and Southwold Railway, Suffolk, is to be requisitioned by the Ministry of Supply and sold for scrap.

THE UNITED STATES MOTOR-CAR INDUSTRY.—The production of motor vehicles in the United States in December, 1940, as recorded by Federal Department of Commerce, totalled 396,530 passenger cars and 87,040 motor lorries, compared with 407,090 cars and 80,260 lorries in November. The total production for 1940 amounted to 3,692,330 passenger cars and 777,030 motor lorries.

ENGINEERING.

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TIME FOR RECEIPT OF ADVERTISEMENTS.

Classified advertisements intended for insertion in the current week's issue must be delivered not later than first post on Wednesday. Alterations to standing advertisements must be received at least 10 days previous to the day of publication. Passed proofs must be in our hands by Saturday morning, otherwise they will be taken as correct. The Proprietors will not hold themselves responsible for blocks left in their possession for more than two years.

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ENGINEERING

FRIDAY, MARCH 21, 1941.

VOL. 151. No. 3923.

RAILWAY PERFORMANCE.

IN normal times, it is possible to obtain a fairly complete picture of the situation and progress of the railway companies from the chairmen's speeches at the annual general meetings, which are usually held within a few days of each other. These occasions give an opportunity for a review of traffic development and some account of new and maintenance works. This year, practically all information on these subjects was missing. The guarded statements made at the recent meetings of the main-line companies, containing nothing likely to be of value to hostile elements, naturally also deprived the shareholders and interested outsiders of information which, usually, they rightly obtain. In view of the statement by the Minister of Information in Parliament, on March 13, about the publication of the reports and chairmen's speeches of public utility companies, it would appear that in some official circles even the meagre information furnished was regarded as possibly too extensive and an even more stringent censorship than the present may be imposed. As, however, the chairmen's speeches have already been published *in extenso*, there can be no objection to commenting on some aspects of them. The financial statements, of which they were largely made up, are of no interest to the Germans and the information on operating conditions contained nothing that they did not know before. Mr. Charles Hambro, for instance, at the meeting of the Great Western Company, said that the diversion of a million tons of coal from coastwise shipping to his line would involve the running of 2,000 additional trains. The Germans know the capacity of our coal wagons and would have no difficulty in computing the number necessary to carry a million tons.

Most of the chairmen made some reference to the criticism which has been directed against the railway companies, largely in reference to inadequate passenger facilities and to delays. Lord Stamp, in particular, at the meeting of the London Midland and Scottish Railway, spoke with some heat on the matter and suggested that this type of uninformed and inconsiderate attack was likely to have an undesirable effect on the keenness and morale of the railway staffs, on which so much now depends. The chairmen unquestionably have a grievance in this matter. Railway servants and officials now find themselves in the position normally occupied by civil servants. They are not allowed to reply to criticism. Civil servants are always, however, at least in theory, protected by the Minister to whose Department they are attached. He is free to defend and explain the action of his subordinates to any extent he may feel it desirable. Railway men have no such spokesman and the most unfounded charges must go unanswered, lest the reply give information of value to the enemy.

It requires little imagination to understand why the railways cannot provide service to the general public of a standard similar to that of peace time. As, perhaps, the most spectacular aspect of the reason, a good deal was said, particularly at the meeting of the Southern Railway, about the Dunkirk evacuation. This involved the running of 734 special trains by that company, the proceeding necessitating extensive assistance by the other main lines. Another matter mentioned was the evacuation of part of the civil population from various areas. This required 300 special trains on the Southern Railway during the year under review, in addition to the carrying of 180,000 people in ordinary trains. In this matter the company escaped more lightly than in the previous year, more than a thousand special evacuation trains having been run in the first five days of September, 1939. At that time, however, railway conditions generally were nearer normal than they are now and difficulties were less. Further trouble was caused by the severe weather of January, 1939, during which, in three days, the London Midland and Scottish Railway was blocked by snow at 313 places, the total hold-up extending to 48,000 hours.

All these matters were of a temporary nature and form no defence to a charge of continued deterioration of service. An adequate reply is furnished by conditions which will endure throughout the war and the effect of many, for a considerable time after its end. As Lord Stamp pointed out, "railways are laid out physically to deal with recognised flows of traffic, and such lines, on the law of averages, are capable of dealing with considerable proportionate increases throughout." Present conditions cut directly across their planned functions. The mere movement of a substantial proportion of the civil population to new areas involves alterations in the distribution of traffic which, in the case of normal population flux, would be spread over many years. If they have to be made in a few weeks or months they must be something of a makeshift. More important, probably, is the hasty construction of new factories in new areas, requiring not only the movement of workpeople, but heavy and continuous goods traffic, frequently involving cross-country running, which introduces delays and difficulties that would not arise could the flow continue along the old main arteries. Possibly the best example of the complete upsetting of the usual traffic flow is furnished by the South Wales coal trade. The railways serving the mining areas of Glamorgan and Monmouth follow the valleys of the southern spurs of the Brecon mountains and are laid out entirely from the point of view of serving the coal ports on the Bristol Channel. The normal haul is about twenty miles. Owing to the loss of many export markets and the restriction of coastwise shipping, coal now has to be transported by rail to destinations throughout the country as far away as London, or further, by routes which were not laid out to handle it.

Added to all these special conditions is military traffic, involving the movement of troops and material to an extent which may be guessed, but which will certainly not be stated. As there is no secret in the fact that it is very heavy and must have precedence, it is clearly a major factor in the deterioration of the facilities provided for the civilian population. As activities have also to be carried on with a depleted staff, under the handicap of the black-out and subject to hindrance caused by

enemy action, the service provided is a matter for congratulation rather than criticism. From the London Midland and Scottish Railway, 12,000 of the staff have joined the Forces, the figure for the Great Western being 8,600, and for the Southern 6,000. This does not mean that the railways are short of staff to this extent, but the substitute labour which has been engaged naturally cannot display the efficiency of hands with years of experience behind them. The inconvenience of the black-out need not be stressed. Everyone has experienced it for himself. Although it has thrown extra work and responsibility on railway operatives, the little delay caused by enemy action is surprising and suggests that this form of warfare, as carried out by the Germans, is less efficient than they would like to believe. A point of much technical interest was mentioned by Mr. Robert Holland-Martin at the Southern meeting. He said that after air-raid damage, in practically every case, current had been available on the conductor rail as soon as the track had been restored. In view of much pre-war discussion about the vulnerability of electrified lines, this information, gained in the school of experience, is of considerable importance.

As already mentioned, much of the time at the railway meetings was given to the discussion of financial matters. It would be outside our province to enter into these in any detail, but in two cases they raised a question of fundamental policy and great general interest. The receipts of the four main-line railway companies, together with those of the London Passenger Transport Board, are now paid into a common pool. A net minimum revenue of 39,850,000*l.* has been guaranteed to this pool by the Government. Actually, for 1940, the revenue was 42,763,000*l.* This difference of 2,913,000*l.* has been made the subject of an attack on the railway companies by certain sections of the daily Press. The recent increases in railway charges are taken as the basis for the criticisms advanced, but it is clear that the real purpose is to press the case for nationalisation. As pointed out by the chairman of the London and North Eastern Company, these critics are actually attacking the system they are advocating. As far as finance is concerned, the railways are already entirely under Government control. They did not inaugurate the pool system, and do not much like it. Even any adjustment of their charges to ensure the minimum revenue to the pool has been taken out of their hands. This is now the business of the Railway Executive Committee, which is entirely under the direction of the Minister of Transport.

It is true that the Railway Executive Committee is largely made up of railway officials, or, rather, ex-railway officials. This is obviously a necessity. In making the appointments to such a committee, the Minister had to choose individuals with railway-operating experience; to have relied on outsiders would have been to invite chaos. These officials, moreover, are not now the servants of their railways, and there is no reason to suppose that they are not acting solely in the interest they now represent. In any case, under any system of nationalisation, the operation of the railways would have to continue under those who already have experience of this type of work, as we presume that even the most nationalisation-minded of our daily contemporaries does not contemplate the appointment of political executives on some Continental models. The question of railway nationalisation, will, for better or worse, certainly come up for discussion after the war, but it is highly undesirable that attempts should be made to utilise present conditions to bring in fundamental changes.

Even with the benefit of this 2,913,000*l.*, the railway companies have not turned into fairy godmothers for their shareholders. The London Midland and Scottish Company, for instance, found itself able to pay 1¼ per cent. on its ordinary stock. Some incidental comparisons illustrating the factitious nature of the criticism of increased railway charges were given by Lord Stamp. During 16 months of Government control, the yield from all increased charges has been 12½ per cent. In the same period, coal increased in cost by 41 per cent., steel rails by 80 per cent., sleepers by 183 per cent., and pig iron by 83 per cent.

A NEW LONDON.

HARD on the heels of Lord Reith's statement, in the House of Lords, on his preliminary conception of the duties of the Ministry of Public Works and Buildings after the war, to which we referred last week, there has come one of the most practicable visions of the London that is to be—or, at any rate, that might be. Mr. W. H. Ansell, the President of the Royal Institute of British Architects, whose outline of "The London of the Future" was presented in a paper delivered before the Royal Society of Arts on March 12, has not only a long and varied list of notable buildings to his credit but, as a former captain in the Royal Engineers, may be assumed to have acquired rather more of the matter-of-fact outlook which engineering occupations develop than has characterised some architects of recent years—and, indeed, of earlier years as well. In addition, as his paper showed repeatedly, he is modern without being "modernist," while appreciating to the full how much of the indefinable charm of London has been due to the great architects and builders of the past and the skill with which they adapted classical forms to the circumstances of London topography and a Northern climate.

To entitle a commentary on Mr. Ansell's paper "A New London" is convenient, although, in fact, it is not altogether in accord with his guiding principle. "I dissociate myself at once from those who would give us a new London," he stated, "I want a vastly improved old London, not improved out of recognition, but retaining every architectural treasure that our fathers have left us, passing them on in our turn, together with our own contribution which the present unexampled opportunity has made possible. London must and shall remain London." Some of the essentials that he postulated are familiar enough; the replacement of slums by "healthy interesting dwellings," the removal from London of industries which are not obliged to remain in the Metropolitan area, the possible resiting of the great markets, and the replanning of the Surrey side of the river, are the more important of the problems mentioned, the solution of which must be taken in hand as necessary components of any wider scheme. More original, however, are his proposals for dealing with London traffic and the reorganisation of the main thoroughfares to meet its needs, while preserving the individuality that these principal arteries have acquired.

There has been a definite tendency, in recent years, to subordinate the consideration of the future London to the urgency of the traffic problem; to make the planning of the structure of the city subservient to that of the roads, and especially the through roads. The Bressey Report emphasised and encouraged this tendency, though the fact must be remembered, in its defence, that it was a report on traffic conditions and their possible amelioration, and not on the reconstruction of London. Mr. Ansell regards the matter from the latter viewpoint and sees in Sir Charles Bressey's proposed viaduct roads from Blackfriars to Brixton, and from Rotherhithe to Forest Hill, merely additions to the 29 miles of railway viaducts which have "stifled and corrupted the reasonable development" of South London. He demands, as a basic principle, that "the replanning of South London shall not be crabbed from the beginning by the dead hand of the Victorian railway engineers," though it is more than a little difficult to see how this primary drawback is to be obviated, even in the century that he is prepared to allow for the full fruition of the suggestion. It may be observed that he takes for granted the provision of the necessary finance; rightly, no doubt, because there can be no question that financial problems will not prevent the development of London, though they may retard it.

Mr. Ansell's approach to the problem is rather by removing from London as many as possible of the causes of present congestion, partly by inducing industries to leave the central areas, and partly by arranging that parking and loading spaces for vehicles shall be provided in the ground floors of new buildings so that the streets can be reserved for transit purposes, as they should be. Larger, but fewer, individual buildings would encourage the preservation of the "community areas" already characteristic of London—Government buildings in Westminster, residential areas in Mayfair and Bloomsbury, etc.—which, as he says, should be served by the great roads, and not governed by them. He visualises a new Cheapside, for example, a street of shops with colonnaded pavements, with an open piazza leading to Guildhall, and space enough around St. Paul's "to free the Cathedral from its jostling neighbours." The towers and steeples of the wrecked City churches he would retain, and where the churches themselves are damaged beyond rebuilding, he would have their sites cleared and planted as oases in the City streets. We would go farther, and suggest that some of the ruins might be preserved as ruins, properly cared for, as are so many ancient abbeys up and down the countryside. The through roads which already exist—for instance, from Shepherd's Bush to the Mansion House, and from Charing Cross to the North—should be made into boulevard highways; a finer long-term investment, he suggests, than the construction of relief roads on new lines.

Above all, however, the rebuilding of London should be conceived as a whole, and not spoiled by piecemeal experiment, architectural or otherwise. As was pointed out by another architect, Mr. G. Berkeley Wills, in a recent letter to *The Daily Telegraph*, probably the best piece of civic planning in London—Nash's Regent-street—was constructed in the cheapest of materials, but was effective because it was designed and carried out as a whole and not in the patchwork fashion that has spoiled the new Regent-street, Kingsway and Aldwych. The same lack of a general architectural scheme is only too evident in many of the City streets where much rebuilding has been carried on during recent years; indeed, the impression is difficult to escape, that the architects of many modern buildings, situated in thoroughfares in process of gradual reconstruction, have been more concerned to introduce deliberate differences in design, possibly in the desire to avoid any suggestion of plagiarism, than to consider the requirements of the street as a whole. The worship of the architectural vista can be overdone, no doubt, but it is a sound principle and most of the large cities in this country would have been the better for its closer observance.

The replanning and reconstruction of London is almost as much a matter of engineering as of architecture, and there are many purely engineering problems involved in its fulfilment on which Mr. Ansell commented only in passing or not at all. There is one point, in particular, at which the two arts make contact, and which is all-important if the completed scheme is to be aesthetically as well as functionally satisfying, namely, that of proportion, with all that the term implies. It was in this respect that Wren excelled. "There are two causes of beauty," he wrote, "natural and customary. Natural is from Geometry, consisting in uniformity (that is, equality) and proportion. Customary beauty is begotten by the use of our senses to those objects which are usually pleasing to us for other causes . . . Here lies the great occasion of errors; here is tried the Architect's judgment; but always the true test is natural or geometrical beauty." The beauty of good engineering design is compounded of both sorts; a construction that is geometrically correct is usually technically sound, but some fore-knowledge of the suitability and properties of its materials and the nature of its purpose is requisite to a full understanding of its qualities and appreciation of the "customary beauty," to which Wren referred. Thus may be justified the contention that true beauty, which must include some sense of fitness for the designed purpose, must depend on line rather than adornment; a principle that too many architects in this and other ages have tended to ignore, if they ever realised it at all. There are indications that the latest phase of this recurrent weakness is passing, fortunately for the future of London; yet the possibility might well be seriously considered, that at least one competent engineer, as well as the artist suggested by Mr. Ansell, should be co-opted on the Planning Board which he proposes, to ensure that the new London shall be designed on "a worthy co-ordinated plan."

NOTES.

THE LEASE AND LEND BILL.

AFTER the protracted debate in the United States Congress, the Lease and Lend Bill, as amended by the Senate, was passed by the House of Representatives on March 11, and immediately received President Roosevelt's signature. Forthwith, the President took action to implement the intention of the Bill, by asking Congress for an appropriation of 1,750,000,000*l.*, in pursuance (in his own words) of "the fixed policy of this Government to make for the democracies every gun, 'plane and munition of war we possibly can." Of this total of 7,000,000,000 dols., the principal items of the intended expenditure are aircraft, 2,054,000,000 dols.; agricultural and industrial commodities, 1,350,000,000 dols.; ordnance and ordnance stores, 1,343,000,000 dols.; manufacturing equipment, 752,000,000 dols.; ships, 629,000,000 dols.; and tanks and armoured cars, 362,000,000 dols. Thus comes into full being what Mr. Churchill justly described as a "monument of generous and far-seeing statesmanship," which would surely have delighted the heart of Commander Josiah Tatnall, U.S.N., by confirming once again his declaration that "blood is thicker than water." Much of the projected aid will require some time for its fulfilment, but every effort is being made to expedite the arrangements for making speedily available the American reserves of foodstuffs, and for accelerating the production of merchant shipping in American yards. The shipping problem being especially urgent, it was announced on March 15, that Sir Arthur Salter, Parliamentary Secretary to the Ministry of Shipping, is proceeding at once to the United States to discuss with President Roosevelt's Government the various forms which American help may take. Sir Arthur will work under the general direction of the British Ambassador in Washington and will be a member of the British Supply Council in North America, while retaining his present office in the Ministry of Shipping. Various unconfirmed rumours have been current regarding the assistance that may be forthcoming in the form of additional naval vessels, but it may be presumed that these questions will not directly concern Sir Arthur Salter. The building programme of the National Maritime Commission is progressing rapidly, however, and it may be supposed that the completion of these new merchant ships will release a corresponding tonnage of older ships, which it may be possible for the British Government to acquire, pending the building of the 60 ships recently ordered from associated companies of the Todd Shipyards Corporation, to which we have made previous reference.

THE LONDON PASSENGER TRANSPORT BOARD.

The seventh report of the operations of the London Passenger Transport Board is unusual in that it covers a period of 18 months instead of the customary twelve, this modification having been made, in pursuance of an Order made by the Minister of Transport, to bring the Board's accounting periods into line with those of the main-line railways and certain other undertakings affected by the Railway Control Order, 1939. Under the pooling scheme introduced by this Order, the Board are guaranteed a net revenue of approximately 4,480,000*l.* per annum, which is sufficient to meet the interest on the whole of the prior-charge London Transport stocks, and about 1½ per cent. on the "C" stock. The financial arrangements, as originally agreed, provided that the cost of making good war damage should be charged as revenue expenditure against the Pool up to a maximum of 10,000,000*l.* for all parties in any one year, but some modification of this provision is probable in view of the introduction by the Government of the War Damage Bill. Estimates showed that the available revenue for the year ended December 31, 1940, was about 42,763,000*l.*, compared with the guaranteed net figure of about 39,850,000*l.*; out of the former total, the Board receive 4,811,981*l.*, which is increased by sundry adjustments to 4,853,236*l.* The interest on the prior-charge stocks requiring 4,080,477*l.*, this left 772,789*l.* for the service of the "C" stock, on which a total of 3 per cent. is being paid for the year. The balance of 1,825*l.* has been carried to the Stock Interest Fund. The amounts set aside for the Renewal and Maintenance Reserves were, respectively, 1,370,000*l.* and 30,000*l.* for the six months ended December 31, 1939; and 2,775,000*l.* and 70,000*l.*, respectively, for the year 1940. During the 18 months covered by the report, capital expenditure was incurred amounting to 8,003,012*l.*; but, for reasons connected with the war, it was considered advisable to suspend operations on certain of the new works, and this was done with the approval of the Minister of Transport. The financial arrangements with the Government provided (as in the case of the main-line railways) that increases in expenditure due to war conditions should be met by corresponding increases in fares and other charges. In accordance with this policy, railway rates, fares and charges were raised by 10 per cent. from May 1, 1940, the increase affecting fares of 5*d.* and over, certain workmen's fares under 5*d.*, and railway season-ticket rates. As from July 3, 1940, 1*d.* road and rail fares were increased to 1½*d.*, 1½*d.* fares to 2*d.*, minimum workmen's road fares from 2*d.* to 2½*d.*, and coach fares (including season tickets) by 10 per cent. On and from December 1, 1940, the increase of 10 per cent. on cheap day return railway fares, and on single and return coach fares, was raised to 16⅔ per cent. From the balance sheet appended to the report, it appears that the capital expenditure upon the railways controlled by the Board, at December 31, 1940, amounted to 94,223,748*l.*; on 'buses and coaches, 12,659,258*l.*; upon trams, 5,062,100*l.*; and upon trolley 'buses, 6,949,930*l.* The total capital expenditure, including the balance of consideration for undertakings transferred to or acquired by the Board under the terms of the London Passenger Transport Act, 1933, amounted to 150,045,379*l.*

THE INSTITUTE OF MARINE ENGINEERS.

The probability of "a really hard struggle at sea this year" was foreshadowed by Mr. Ronald Cross, M.P., the Minister of Shipping, speaking at the annual luncheon of the Institute of Marine Engineers on Friday last, March 14. Mr. Cross, who was proposing the toast of "The Institute of Marine Engineers," to which the President (Sir Percy Bates, Bt., G.B.E.) responded, paid a warm tribute to the work of seagoing engineers in maintaining the essential flow of commodities on which the country depended. On behalf of the Ministry, he said, he wished to assure them that their work was not being overlooked, and that the Ministry was anxious that it should receive full recognition. To the end of February, 76 awards for gallantry had been made to ships' engineers. As an example of the deeds which had earned these awards, he cited the case of a ship which was attacked with bombs by enemy aircraft. One bomb penetrated the side of the ship and came to rest on the stokehold floorplates. The ship's engineers first plugged the hole in the shell; then they removed the detonator from the bomb, hoisted it up a ventilator on to the deck, and—"as they thought it might be of technical interest to the Admiralty"—brought it into port. Responding to the toast of "The Rt. Hon. the Lord Mayor and the Corporation of London," proposed by Sir Julian Foley, C.B. (past-president), the Lord Mayor spoke of the many spontaneous gifts that had been made to the City Corporation towards the restoration of Guildhall, following the fire-bomb attack of December 29. They included a contribution of 318*l.* from the officers and ship's company of the liner Queen Mary, the result of a collection made at the instigation of an able seaman; and a monthly deduction of 5*l.* from his pay, for the duration of his service with the Allied mercantile marine, made by a Norwegian ship's officer. The report of the Council for the year 1940, presented and adopted at the annual general meeting, which preceded the luncheon, showed a slight decrease in the numbers on the membership roll, the total standing at 4,168 on December 31, 1940, as compared with 4,224 at the beginning of the year. It was announced that Sir Percy Bates had accepted the unanimous invitation of the Council to continue in the office of President for a third year. In the course of the proceedings, Sir Percy presented the various Institute awards made by the Council during the year. These comprised the Denny Gold Medal to Mr. S. A. Smith, M.Sc., for his paper on "The Powering of Ships"; the Institute Silver Medal, to Professor E. Forsberg, for his paper on "Oil Purifying with Continuous Lubrication,"; the Junior Silver Medal and Premium, to Mr. R. A. Collacott, B.Sc., for his essay on "Heat Insulation of Cold Stores"; and the Extra First-Class Engineers' Certificate Medal, awarded on the recommendation of the Chief Examiner of Engineers, Ministry of Shipping, to Lieut. (E) J. F. Tucker, R.N.

REGISTRATION FOR WAR WORK.

Two new features of the Government's arrangements for the increase of the man-power and woman-power available for work of national importance were announced by the Minister of Labour and National Service in the address which he broadcast on Sunday last. In order that it may be ascertained how many are doing essential work, men between the ages of 40 and 45, not employed in certain industries, are to register, those between the ages of 41 and 42 on April 5. The facilities for training have been increased and improved. There have been difficulties in the past, Mr. Bevin said, about pay. It has been decided to continue the existing arrangements up to March 31, but from that date onward people in training under the Government scheme will be paid "proper wages." There is also to be a national registration of women of the ages of 20 and 21, beginning with the 20's on April 19. After registering, they will be interviewed as required, and directed to places in which they can be most usefully employed. A training scheme for women is in existence, and among the duties for which they are required is shell filling.

ELECTRICITY SUPPLY IN THE UNITED STATES.

According to the report of the Edison Electric Institute for the year ended December 31, 1940, the generating capacity in the United States at that date was 40,330,000 kW, of which 1,790,000 kW had been added during the year. Schemes projected for the present year cover 3,412,000 kW, while an addition of 2,302,000 kW is scheduled for 1942. These extensions are due, in great part, to the development of the defence programme. In this connection the report regards it as noteworthy that isolated industrial steam plants, which increased in capacity by 120,000 kW in 1940, will increase by 250,000 kW in 1941, and, as far as schemes have yet been prepared, by 110,000 kW in 1942. During 1940, the sum of the peak loads on the various systems for the country as a whole was about 10 per cent. above that of 1939, the total installed generating capacity being about 30 per cent. in excess of the sum of the individual peak loads. The output in 1940 from all undertakings, private and public, contributing to the public supply, was 140,750 million kWh, as compared with 126,666 million kWh in 1939. Fuels of all kinds produced 94,500 million kWh, an increase of 13 per cent. over the previous year, while water power provided 46,250 million kWh, an increase of 7½ per cent. The water power production was augmented by increased rainfall during the second half of the year. On the basis of ten months' actual results, together with estimates for the last two months, it is assumed that 23,250 million kWh were sold for domestic purposes, 22,250 million kWh to small commercial consumers, 59,550 million kWh for industrial power production, and 13,450 million kWh for miscellaneous purposes, making a total of 118,500 million kWh. There were 30,091,500 consumers, an increase of 986,000 during the year; 2,100,000 were farm consumers. About one-third of the occupied farms are now taking an electric supply. The report states that new army cantonments and camps, as well as new air bases and munitions factories, whatever their location, have been found, practically without exception, to be reasonably within reach of existing power lines, so that it has been possible to arrange an adequate and reliable supply. Moreover, so far as can be foreseen (except, perhaps, in isolated situations), there will be an ample supply of power in 1941 and 1942 to operate all the new munitions factories required. If further extensions take place, new generating capacity can be added to supply them as rapidly as may be necessary.

LETTERS TO THE EDITOR.

GRAPHICAL CALCULATION OF RIGHT-ANGLE HELICAL GEARING.

TO THE EDITOR OF ENGINEERING.

SIR,—With reference to the article on the above subject published in your issue of March 7, on page 183, I agree that it is quite impossible to find an algebraic solution for the equation

$$R \sec \alpha + \operatorname{cosec} \alpha = \frac{C \cdot P_n}{\pi} = c$$

which has to be used to determine the centre distance of helical gears with crossed axes, and the diagram published in the article is therefore very useful. It may be mentioned, however, that there exists a simple analytical method of designing such a gear with the minimum centre distance. We have only to differentiate the above equation, yielding

$$-\frac{R \cdot \sin \alpha}{\cos^2 \alpha} + \frac{\cos \alpha}{\sin^2 \alpha} = 0$$

or

$$-R \cdot \sin^3 \alpha + \cos^3 \alpha = 0.$$

This at once gives the angle α_m for the minimum centre distance

$$\operatorname{cotan}^3 \alpha_m = R$$

$$\operatorname{cotan} \alpha_m = \sqrt[3]{R}$$

and

$$\alpha_m = \text{arc} \cdot \operatorname{cotan} \sqrt[3]{R}.$$

Yours faithfully,
PAUL GRODZINSKI.

88, Robin Hood-lane,
Sutton, Surrey. March 15, 1941.

RELEASED TEXTILE WORKERS.

TO THE EDITOR OF ENGINEERING.

SIR,—The recent decision of the Government to release large numbers of workers from the textile trades offers great and immediate possibilities to all engineers to develop the dilution of their present labour on a large scale and thereby to make possible large increases in their night-shifts, which in many cases (of course, with notable exceptions) are entirely inadequate. Thousands of unskilled men, youths and women, who have had no factory experience at all, have proved themselves very apt pupils and are already doing splendid work all over the country. Workers from the textile trades, however, have the great initial advantage of factory experience. They are accustomed to workshop conditions and they possess deftness and manual dexterity of a high order, and it is certain that they will require an even shorter period of training than those who have not had the same experience.

Some training, however, will be necessary and it is urgent that no time should be lost. While Government Training Centres and some Technical Colleges are doing useful work in the training of unskilled labour, both these institutions have attempted far too elaborate methods of teaching, with the result that the period of training has been long drawn out and the output of trained labour, in consequence, entirely inadequate. From a long experience, I am confident that by far the best training can be given in the thousands of workshops throughout the country. Here the necessary machinery, materials and tools exist. Foremen are available to supervise training and the actual teaching can be done by the chargehands and by the workers already employed.

While some of this unskilled labour possesses exceptional aptitude and has shown itself capable of dealing with work of a most important character, by far the larger number of new recruits will be called upon to carry out only comparatively simple repetition operations, and on work of this character willing learners, within a week or less, can become quite efficient and in a very short time they will be competent to act as instructors in their turn.

I look upon the present as a very great opportunity, of which I am sure full advantage will be taken in all war industries. Nor must we lose sight of the ever-present necessity of up-grading. Skilled men should do skilled work only and should not waste their time on simple jobs. Operators of intelligence and ability should be given the chance to become setters-up. It is only by a determined effort in this direction that the shortages in the higher ranks of labour will be overcome.

Yours faithfully,
ALFRED HERBERT.

Dunley Manor,
Whitchurch, Hants. March 13, 1941.

THE FUTURE OF APPRENTICESHIP.

TO THE EDITOR OF ENGINEERING.

SIR,—I am very surprised that no one has taken the trouble to comment upon your editorial under the above title, and the article by Mr. C. J. Atkins, which were published on February 7, and I sincerely hope that this is not to be taken as evidence of apathy regarding the future of the young entrants to the engineering industry. The Lewis Committee considered the whole matter during the last war, but, unfortunately, its recommendations were never given a proper trial. The present seems to be an opportune time to review the whole position in an attempt to evolve a national plan for apprenticeship, in the fervent hope that we may avoid the troubles which followed the 1914-18 upheaval. It is rightly pointed out that the large concern has little difficulty in evolving and operating suitable training schemes for its young people, but it should be noted that only about 40 per cent. of the total number of apprentices are employed by such firms. The problem of catering for the proper training of the other 60 per cent. is obviously of first-class importance, and merits very careful consideration.

Mr. Atkins suggests that much of the training should be taken over by the Government training centres, which are controlled by the Ministry of Labour and National Service. He also stated that "throughout the period, the lad should be given facilities for technical training, following some progressive course, such as that for the National Certificate." Such courses are now in operation in our technical colleges, controlled by the Board of Education through the local Education Committees. This prompts me to point out that one of the greatest troubles with the present arrangements is that there are too many gaps and insufficient co-ordination between the various parts. Conditions would not improve by bringing another Government department into the scheme, when the work can very well be done by one of the present participants.

The nucleus of a training centre already exists in every industrial town in the local technical college, and these are now showing, through their participation in the various emergency training schemes, that the acquisition of skill, the learning of techniques and the study of technology, can all be undertaken in the one establishment. Employers should be encouraged to release apprentices for part-time study in the class rooms and workshops of the local colleges, so that the theoretical and practical work can be efficiently dovetailed together and thus produce a truly co-operative course. This is the only way to produce intelligent and adaptable workmen and so keep our industrial prestige.

Before such a plan could be put into operation, it would be necessary to overhaul the nation's educational system, and, in particular, to close the gaps. Why not give effect to the continuation school clauses of the Fisher Act, and bring to every young person the advantages which are so evident in the Rugby area? This would undoubtedly lead to the raising of the general level of attainment of all our young workers, and would pave the way for a greater demand for the enlargement of the facilities for part-time study up to the end of the apprenticeship period. The problem of making the best use of our material resources is attracting much attention at the present time, but we should not lose sight of our most important possession, namely, human skill and ingenuity. We ought not to tolerate a position which allows our young people to "pick up" a trade.

Yours faithfully,
G. F. JOHNSON.

March 10, 1941.

OBITUARY.

MR. A. C. CUNNISON.

IT is with deep regret at the loss of a valued member of the publishing staff of ENGINEERING that we record the death of Mr. Alexander Cleland Cunnison, which took place on March 11 at his home in Newcastle-on-Tyne. Mr. Cunnison, who was the younger son of the late Mr. J. D. Cunnison, of Dulwich, was born in Dundee in 1875, and had acquired a varied experience of newspaper publishing on the staff of several London papers before coming to this journal. A keen Volunteer, he joined the London Scottish as far back as 1890, and rejoined in 1914, proceeding overseas in October of that year. Subsequently he was granted a commission in the Royal Flying Corps as equipment officer, in which capacity he was stationed in Egypt until the close of the war. He went to Germany with the Army of Occupation on the conclusion of hostilities, and spent some time at Cologne before being demobilised. He joined the staff of ENGINEERING in May, 1925, as advertising representative in the South Wales district, but was transferred, six months later, to the North-East Coast. In 1930, his district was extended to include the whole of Scotland, where he assisted the late Mr. W. K. Dane until 1935. Since then, he had been our sole representative in both areas. Mr. Cunnison was an enthusiastic golfer and a couple of years ago was captain of the City of Newcastle Golf Club. Latterly, his health had not been good and he suffered much from the after-effects of gas poisoning, a legacy from the Battle of Loos. The exceptionally severe weather experienced in the early part of this year on the North-East Coast tried him severely, and undoubtedly hastened his end. His many friends in that district, and in Scotland and elsewhere, we feel sure, will share our regret at the loss of a colleague whose genial personality will not be readily forgotten.

MR. LOFTUS P. PERKINS.

ELDERLY men who have been long retired from active business and who have outlived their immediate relatives may easily slip from this world into the next without the knowledge of their former associates, especially if they are of so modest a disposition as was Mr. Loftus Patton Perkins, of whose death we have learned only recently, although it took place so long ago as September 5, 1940. Mr. Perkins, who was born in 1867, was a son of Mr. Loftus Perkins, M.Inst.C.E., and thus was a direct descendant of Jacob Perkins, of high-pressure steam fame. Loftus Patton Perkins received his general education at Caversham and subsequently at London University. He entered his father's firm, the Perkins Engine Company, then in Seaford-street, London, and was connected in turn with their successors, Werner, Pfleiderer and Perkins, Limited, and the present firm of Messrs. Baker Perkins, Limited, now of Peterborough, as well as with Messrs. A. C. Wells and Company. He had been a member of the Junior Institution of Engineers for nearly half a century, having joined in 1891, when it was known as the Junior Engineering Society. To its *Transactions* he contributed, in 1927, an informative paper on "Pioneers in High-Pressure Steam." It provided a survey of the work of the several generations of the Perkins family in this field which is of particular historical value as, with his death, this direct line becomes extinct.

DR. E. L. INCE.

As we go to press, we have learned with regret of the death, on March 16, of Dr. Edward Lindsay Ince, lecturer in technical mathematics at the University of Edinburgh. Dr. Ince, who was only 49 years of age, was a native of Staffordshire. He was educated at Perth Academy and at Edinburgh University, of which he was D.Sc., subsequently proceeding to Trinity College, Cambridge, where he graduated M.A., and to Paris. After six years as lecturer at Liverpool University, he went to Egypt in 1926 as Professor of Pure Mathematics in the Egyptian University, returning to this country in 1931. He was the author of a number of mathematical works.

UNIV. OF MICH.

MODERN METHODS OF EXCAVATION WORK.

(*For Description, see Page* 235.)

FIG. 5. OPEN-CAST COAL MINE.

FIG. 6. BENCHES IN FUSHUN OPEN-CAST COAL MINE.

FIG. 7. ROAD CONSTRUCTION WITH BULLDOZER.

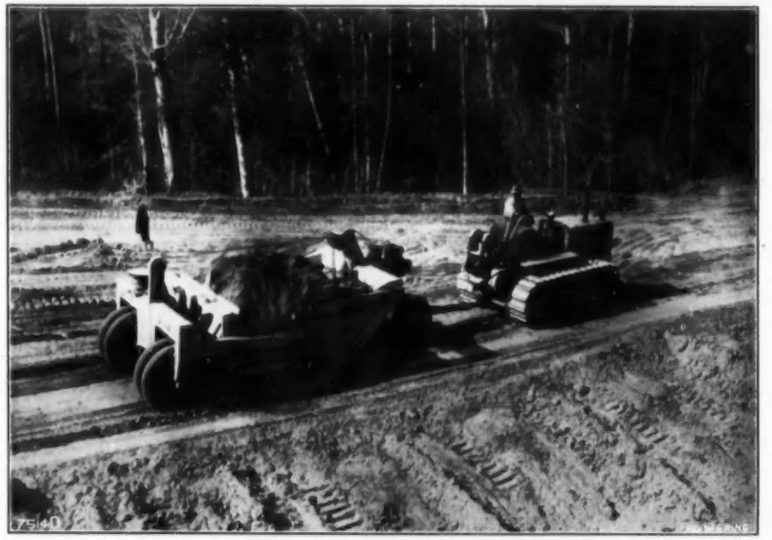


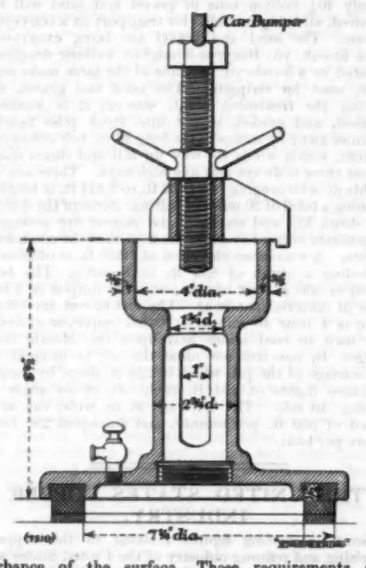
FIG. 8. LOADED TRACTOR-DRAWN SCRAPER.

(*To face page* 235.)

TESTING THE PERMEABILITY OF ASPHALTIC SURFACES.

SINCE one factor of the durability of roads and similar constructions finished with an asphaltic surface is the degree of permeability to water, the question of waterproofing surfaces of this kind is of considerable importance in such cases as aerodrome runways. An instrument known as a permeometer has been used for some years for testing asphaltic surfaces, and a description of a simple type of permeometer developed by Mr. S. C. Ells, of the Department of Transport, Ottawa, Canada, is given below. Mr. Ells, who was associated, during the summer of 1940, with the surfacing of airport runways constructed under the Empire Air Training Plan, made use of a permeometer in accordance with a specification of the Asphalt Institute, but finally employed the type shown in the accompanying illustration, which type he found to be quite satisfactory in service and to be simple to construct and operate. It consists essentially of an open cylinder with a base flange faced with a rubber ring. The instrument is held down on the surface to be tested and filled with a measured amount of water, the amount leaking through the surface in a known time giving a measure of the permeability of that surface.

One of the first requirements of a permeometer is that it must be readily transported and it must be held down on to the surface to be tested with sufficient force to ensure an effective seal without disturbance of the surface. These requirements are met in the instrument shown in the illustration by making it easy to assemble and by utilising part of the weight of the transporting motor car to hold it down. The cylinder is expanded at the top into a cup, on the upper edge of which rests a "spider" made from a short piece of stiff tube to which three radiating arms are welded. A bolt, having a nut with short rods welded to three of its faces, passes through the spider, the nut bearing on the spider top. The head of the bolt is slotted to receive the under edge of the car bumper and the whole assembly is then virtually equivalent to a lifting jack; its function, however, is to impose a load, varying with the weight to the car used, on the seating flange at the bottom of the cylinder. This flange is faced with an insert of fairly hard rubber with a thinner, and readily renewable, liner of softer rubber.



It is only very rarely that a watertight seal can be obtained by the rubber alone and any leakage vitiates the reading to the instrument. The surface to be tested, in consequence, is usually faced with a ring of smooth putty. This is readily formed by moulding the putty round a disc of wood of the same diameter as the interior of the rubber seating, viz., 7⅛ in. The putty ring is normally about ¼ in. thick by about 1 in. wide. On completion of the ring the disc is given a half turn, to break the bond between the putty and the wood and is then withdrawn. The permeometer is then placed on the ring and the load applied. The putty may be used four or five times and its application generally proves effective in completing the seal. Occasionally, however, during wet weather or when the surface has fine hair cracks, the putty ring is not sufficient and a ring of black roofing cement is applied to a depth of about ¼ in., on the top of which, when set, the putty ring is formed. The use of this cement, however, makes it advisable to use fresh putty for each joint. The procedure mentioned above may seem complicated but, in practice, when two men are employed, the average time for setting up the permeometer and taking the necessary readings is about 6 minutes.

On aerodrome runway construction the tests have usually been made at points from 200 ft. to 300 ft. apart in the longitudinal direction. The points are staggered across the surface at the sides and centre, the lateral points being about 6 ft. from the edge. If it is found necessary to use roofing cement base rings, these should be laid down in advance. It may take about half-an-hour to lay down some 20 of these rings, so that by the time the last one is in place the first will have set sufficiently hard for the putty ring to be placed on it and the test proceeded with. It is obvious that there are certain conditions under which the permeometer cannot be used at all, viz., on a ridged or wavy surface; when the surface is of such an open texture that the water may percolate under the sealing ring; and when there is a clay film on the surface. In the latter instance, however, the use of a stiff scrubbing brush will generally prove effective, and in all cases the surface should be well brushed before the sealing rings are applied.

The body of the cylinder is provided with a window through which the water level is observed, the edge of the window being fitted with a scale graduated in divisions representing 10 cub. cm. of water, the whole scale covering 100 cub. cm. The screwed hole seen below the window is for a plug, employed in calibrating the instrument. The pet cock on the flange is used to release entrapped air or to draw off surplus water if the level rises above the top graduation when filling. Normally, the cylinder is filled rapidly up to the top graduation and the time is noted, other readings, and times, being taken as the water level falls due to the permeability of the surface. The area of the surface exposed to the column of water, allowing for reduction by compression of the rubber is 40 sq. in. The Asphalt Institute suggests that sealing is necessary when permeability tests show leakage in excess of 2·5 cub. cm. per square inch of area in less than the following periods of time: On bituminous macadam, 120 seconds; on oil mixes, cut backs, etc., 180 seconds; and on asphaltic concrete, 180 seconds. Theoretically, surface sealing coats are airtight and watertight, but actually there is usually some leakage. Mr. Ells has "arbitrarily adopted a permissible leakage of 35 cub. cm. of water in 180 seconds." If this is the total leakage as read on the scale, and taking an area of 40 sq. in., the leakage rate, viz., 0·875 cub. cm. per square inch of area, is much less than that suggested by the Asphalt Institute, but it must not be overlooked that the Institute rate is one indicating that the surface requires sealing, while Mr. Ells' figure is for a surface having a satisfactory degree of resistance to water penetration.

The Institute, moreover, suggests that "during the course of construction of an asphaltic concrete project, a permeability test should be made after each change in mixture and at regular intervals through the job to insure that the surface course be reasonably watertight. These tests should be taken at least once in each mile of surface laid. . . . For bituminous macadam, prior to the acceptance of the job, the test should be made at least once in each half-mile of pavement laid. . . . When resealing is necessary to correct permeability, duplicate tests should be taken following sealing operations. . . ."

We are indebted to our contemporary, *Roads and Bridges*, published by Messrs. The Canadian Engineer Publications, 341, Church-street, Toronto, Ontario, Canada, for the information on which the above article is based.

HELMETS AND RESPIRATORS FOR CIVILIANS.—The Minister of Home Security is anxious to secure the greatest possible distribution of the available supplies of steel helmets and of service and civilian-duty respirators. Many cases arise in which the same individual is a member of a Civil Defence service under a local authority, or of the Home Guard, and may also undertake to perform, at his place of employment or elsewhere, duties for which similar equipment is provided. Mr. Herbert Morrison, therefore, asks all employers, in making any distribution of helmets and respirators to their employees, to find out whether any man or woman concerned already possesses a steel helmet or gas mask of the service or civilian-duty type, and, if so, not to issue additional ones. In cases in which the double issue has been made, Mr. Morrison appeals to the recipients to return the helmets and respirators which they have received from their employers. There are also many persons who, as A.R.P. workers in some capacity, have in their possession a civilian-duty or service gas mask, and also the civilian respirator issued to them as ordinary members of the general public. These are asked to return their civilian gas masks to the local authority.

METHODS OF EXCAVATION.*

By WILLIAM BARNES, M.I.Mech.E.

(*Concluded from page* 197.)

THE largest open-cast copper-mine in the world, in terms of copper production and ore reserves, is situated at Chuquicamata, Chile, and is owned by the Chile Exploration Company. The mine, operated on the bench system, is about 8,400 ft. long, with a maximum width of about 3,000 ft., and the deposit has been proved to a depth of 1,900 ft. Fifteen benches have been opened up to a total depth of 725 ft. The transportation system has been entirely electrified and nineteen 75-ton to 87-ton electric locomotives are in service. Formerly, most of the "clean up" was done by ¾-cub. yd. Diesel-engined shovels, but these have been replaced recently by Diesel-powered caterpillar bulldozers. Over the entire period of operation, 41 steam, electric, and Diesel-engined shovels have been used, but at present 21 shovels are in use, all electrically operated. Again, 4-cub. yd. railroad-type shovels and 8-cub. yd. long-boom shovels were used from 1917 to 1926, but since that time 4-cub. yd. full-circle electrically-operated shovels have been adopted as standard.

More open-cast coal mining is carried out in the United States than in any other country in the world, and this accounts for the introduction and development during comparatively recent years of huge stripping-shovels and draglines, together with heavy quarry-type shovels for digging the materials. One firm alone, the Bucyrus-Erie Company, has constructed more than 200 big stripping shovels, more than 300 quarry-type shovels, and several hundred "walking" draglines. The coal seams, which are more or less horizontal, range in thickness from about 2 ft. to 6 ft., with an average of about 3 ft. The cover, or overburden, which must be removed to obtain access to the coal, is from 20 ft. to 80 ft. deep, with an average of about 40 ft. to 50 ft.; it is dumped, usually by means of big stripping shovels (see Fig. 5, Plate XVIII), or draglines, and sometimes both, over on to the ground from which the coal was removed on the previous cut. Some of these machines, mounted on crawler tracks, weigh from 1,000 tons to 1,500 tons and are fitted with buckets of up to 32 cub. yd. capacity on the shovels and of up to 17 cub. yd. on the draglines. The output obtained from the largest machines would require the services of 1,500 to 2,000 men if it were possible to do the work by means of hand labour. Long-boom shovels fitted with buckets of from 6 cub. yd. to 32 cub. yd. capacity are chiefly used to strip the coal. Usually, the shovel has a sufficient dumping reach to deposit the whole of the material in the open cut, but in some pits where the cover is 50 ft. deep or more, the shovels are supplemented by long-boom draglines with booms 150 ft. to 200 ft. long. These follow the stripping shovel and remove a portion of the top cover of the next cut so as to reduce the working depth for the shovel. In several pits scrapers are used to remove a portion of the top cover in order to enable the stripping shovel to deal with the remainder. Coal-loading shovels, with buckets of 1½ cub. yd. to 7 cub. yd. capacity, follow behind the "strippers" and load the coal. Some of these shovels are of the usual heavy full-circle quarry type, with radial bucket arms, while others, specially built for coal loading, have a horizontal thrust by means of which the shovel teeth can better penetrate the coal strata and partings and clean up the bottom.

In the United States about 5 million tons of anthracite coal is obtained by open-cast mining methods, chiefly in Pennsylvania. Most of the anthracite deposits, unlike the almost level beds of bituminous coal, lie in steeply-pitched basin-like deposits. In order to obtain access to the coal around the sides and in the bottom, the whole of the interior, consisting chiefly of rock, has to be taken out layer by layer and dumped on the surface around the top of the deposit. The rock is loaded by a 4-cub. yd. quarry-type shovel into 13-cub. yd. compressed air-operated dump cars, which are hauled up an incline 1,300 ft. to the surface. The coal is loaded into 5-ton mine cars by a 1½-cub. yd. shovel for transport to the shakers, screens, and washers.

Japan possesses enormous coal deposits in Manchukuo, which are estimated to contain a total of at least 10,000 million tons. Included in this total is Fushun, the largest open-cast coal mine in the world, situated about 30 miles east of Mukden, with coal reserves estimated at approximately 1,000 million tons. A view of this mine is shown in Fig. 6, Plate XVIII. The coal should not be confused with the open-cast brown coal or lignite deposits found in Germany, as it is a good, hard, bituminous coal. The surface of the seam dips

* Dugald Clerk Lecture entitled "Methods of Excavation Work at Home and Abroad," delivered before The Institution of Civil Engineers, on Tuesday, November 19, 1940. Abridged.

considerably from about 50 ft., where the workings commence, to a maximum of 450 ft.; at the present rate of working, the maximum depth will probably not be reached for 100 years. The overburden or cover, estimated at 5,000 million tons, consists of oil-shale containing an average of 6 per cent. of oil. In order to avoid having to dump this overburden to waste and to provide a supply of home-produced crude oil, especially for the Japanese navy, a large shale-oil plant was erected in 1928-9. In 1936, this plant employed about 1,200 men and produced 66,000 tons of crude oil, 20,000 tons of paraffin, and 16,200 tons of petrol, in addition to coke and other by-products. Since then it has been increased enormously. More than twenty excavators are employed at Fushun to remove first the oil-shale overburden and then the coal. Large steam endless-bucket excavators, long-boom steam shovels, and electric quarry-type shovels are employed to load the shale into wagons for transportation to the shale-oil plant. The coal is removed from a series of wide benches stretching down to the bottom of the pit; these are about twelve in number, and are about 20 ft. high. Until some ten years ago all the coal was obtained by means of hand labour, but electric shovels were then introduced to dig the coal and load it into long trains of wagons standing on railway tracks leading to an incline more or less centrally situated in the workings, whence they are brought to the surface by means of powerful haulage systems operating on about six inclined tracks.

As at most other quarries and open-cast mines, the full-circle electric quarry-type shovel is universally favoured for the excavation of limestone, etc., for the manufacture of cement. In a typical limestone quarry, blast-hole churn drills are used to drill the holes for explosives for blasting the material, which is picked up by two 3¼-cub. yd. quarry-type shovels in the bottom of the quarry. The clay required is excavated by means of an endless-bucket excavator. For chalk, which can be readily excavated without the assistance of explosives, the 2½ cub. yd. electric quarry-shovel is generally accepted as the most suitable size and type of machine for outputs ranging from 120 tons to 150 tons per hour. Full-circle quarry shovels of smaller capacity are usually employed to excavate the clay. A new limestone quarry in Pennsylvania has adopted motor-trucks for transporting the limestone from a 4-cub. yd. shovel to the weighing-scales and crusher, and to take the overburden from a 2½-cub. yd. shovel to the dump. Five 15-ton end-dump trucks are used, two to remove the overburden and two for the limestone. The fifth truck is kept in reserve.

The heaviest excavating job in Great Britain is on Penmaenmawr mountain, North Wales, where two Bucyrus-Erie 120B 4-cub. yd. electric quarry shovels are excavating granite 1,340 ft. above sea level. The bench system of working is adopted, the benches being from 90 ft. to 100 ft. deep. Holes about 20 ft. deep are drilled and loaded with about 100 lb. of black powder. The usual practice is to shoot down 1,000 tons to 3,000 tons at a time. The rock is loaded into trains of side-tip wagons, designed by the Penmaenmawr Company, and is hauled to the crushing plant, which has a daily capacity of 4,000 tons.

Under the heading of tractor equipment, come graders, elevating graders, bulldozers, bullgraders or angledozers, and scrapers. The use of the ordinary road-grader has not developed to any extent in Great Britain, as our network of surface roads is more complete than in America; on that continent, however, the road grader has been, and still is, responsible for making and maintaining many hundreds of miles of unsurfaced or "dirt" highways. During recent years, since the introduction of crawler-track Diesel-powered tractors, extraordinary strides have been made in the design, application, and size of the other equipments mentioned. Bulldozers and bullgraders have numerous uses, and are becoming indispensable on many excavating jobs. Dirt can be moved lengthwise for distances of up to 100 ft. to 200 ft. with a bulldozer more cheaply than with other forms of excavating equipment. A bulldozer employed on making a road is shown in Fig. 7, Plate XVIII. Although the method of shifting materials by a bulldozer or bullgrader may seem crude, as the load is merely pushed by a blade in front of a tractor along a surface, efficient operation requires a considerable measure of skill. In determining the proper method of applying bulldozers and bullgraders to any particular earth-moving project points such as gradients, sorting, load-hauling, and idle travelling distances and speeds require careful consideration if the maximum efficiency is to be obtained. A recent job in the Fen country will serve as an example of the work of a bulldozer on a 70-h.p. tractor. This equipment was used to spread a spoil-bank alongside a drain; the average height of the bank was 6 ft., and the average width at the base 20 ft. The material, consisting of silt, sand, and clay, was spread over the land adjoining the drain over a distance of about 150 ft., and the ground was then cross-levelled. In a working week of 70 hours, this bulldozer spread 1,320 linear yards of bank, representing an average output of approximately 124 cub. yd. per hour. To have obtained similar results with a dragline, once the only method, at least four to five times the capital expenditure required for the bulldozers would have been necessary; the operating costs would have been considerably higher, and the job would not have been done with anything like equal efficiency.

In many ways the use of scrapers begins where bulldozers and bullgraders leave off, although some jobs can be done only by bulldozers or bullgraders, while others can be done only by scrapers; five or six years ago it was doubtful whether there were a dozen scraper units in Great Britain. Now hundreds are in use on all kinds of constructional and earth-moving jobs all over the country. They combine in a single unit the two operations of digging and transporting. In addition, with one form of scraper, the material, after being transported, can be spread in layers of various thicknesses upon the dump. This form, which dumps its load between the four wheels on which it is carried, is by far the most popular in Great Britain. A loaded tractor-drawn scraper is shown in Fig. 8, Plate XVIII. Another form of scraper, usually hydraulically operated and mounted on two wheels, dumps its load at the rear only, and thus has not the spreading ability of the four-wheeled type.

Broadly speaking, a scraper can be described as a dragline bucket mounted on wheels by means of which it can, when full, be transported any economical distance for dumping. Even the digging action is similar to that of a dragline bucket, because the bowl or body of the scraper is fitted with a cutting-lip to which power is applied to excavate the material. The thickness of cut can also be controlled like that of a dragline bucket. The digging effort applied to the lip of a dragline bucket by means of the drag-rope is roughly ten times greater than the cutting or digging effort on the cutting-edge of a scraper of equal capacity. The scraper is unable to dig such heavy material as a dragline bucket, and cannot take such a thick cut, even in material within its digging capabilities, so that it requires a longer digging distance in which to fill. Generally, scrapers are suitable only for ploughable material, or for other materials which have been loosened by a ripper or scarifier.

Scrapers of the type referred to so far are most efficient on jobs involving hauls or transport distances of from 300 ft. to, say, 1,500 ft.; thus they are outside the largest dumping range of a standard shovel or dragline, but are still short of the range wherein a shovel or a dragline can be used profitably in conjunction with a locomotive, dump-cars, and railway tracks or motor trucks. The figure of 1,500 ft. is arbitrary: in some instances, scrapers with track-type tractors have been used for work involving one-way hauls of up to 3,000 ft., but for long distances very careful calculations are necessary to ensure that such equipment is likely to prove more economical than alternative methods.

An alternative method, when the travelling distance is uneconomical, is the use of a single-bucket excavator, loading into dump-cars on railway tracks, or into motor-trucks or dumpers. Another alternative is the wheel tractor-scraper, *i.e.*, a tractor mounted on big pneumatic tyres, instead of crawler-tracks, hauling a scraper which, during the digging operation, is assisted by a crawler-mounted tractor working as a "pusher." When the scraper is full the pusher-tractor is withdrawn and the wheel-mounted tractor, still coupled to the scraper, hauls it to the dump. With this form of equipment travelling speeds of about 20 m.p.h. can be obtained; thus the time occupied in hauling the loaded scraper to the dump is reduced considerably and consequently the length of economic haul is increased, so that one-way hauls ranging from 2,500 ft. up to limits undefined by present experience, but approaching 5,000 ft., become a reasonable proposition. Wheel tractor-scrapers depend upon the additional tractor employed as a pusher during the digging operation, since the tractive effort of the rubber-tyred driving wheels of the tractor itself is not usually sufficient to dig and fill the scraper to reasonable capacity.

Many kinds of excavation work are suitable for scrapers, the chief of which is probably a "cut and fill" job on undulating ground. They are particularly useful for levelling aerodromes, factory sites, etc., and also for dam and bank construction; road grading; levee building; drain, canal, lake, and pond excavations; stripping quarries, etc. One of the largest jobs upon which they have been used was the construction of the Hansen dam, near Los Angeles, California, during 1939, involving the excavation of more than 14 million cub. yd. of material from borrow-pits. The scraper equipment included 15 scrapers of 24-30 cub. yd. capacity, 22 crawler Diesel-engined tractors, 28 trucks, and four motor graders. In order to reduce the loading time, and to provide additional power for filling the scraper to its utmost capacity, a tractor-pusher was used during the filling operation. All tractors were fitted with bulldozers to assist in maintaining the digging-slope at a uniform accurate gradient. The wide roads between the borrow-pits and the dam were very carefully maintained so as to obtain the highest possible travelling speed, which averaged about 12 m.p.h. with the fully-loaded scraper, with a maximum of 20 m.p.h. on the return trip. The length of haul attained a maximum of about 6,500 ft.

A tendency is developing for the use of motor trucks, scrapers, bulldozers, etc., in place of locomotives, rails, and rail-trucks for dealing with excavated material, and belt conveyors are also receiving greater favour. A notable example is the installation at the Grand Coulee dam, in the United States, of a complete belt conveyor system over 5 miles in length, which removed more than 10 million cub. yd. of excavated material and conveyed the concrete aggregates required for the construction of the dam. The material, after being broken down, was delivered to 42-in. tributary conveyors, which carried it to a central hub feeder, whence it flowed in a steady stream to a 60-in. belt conveyor, 4,648 ft. in length, consisting of nineteen flights of a maximum slope of 14 deg., and from 156 ft. to 450 ft. in length, with a gross lift of 626 ft. The belt speed was 620 ft. per minute, and the output was 2,500 cub. yd. per hour. Motors of 200 h.p. were fitted to each of the flights, the total power required, including the tributaries and a stacker, being 5,200 h.p.

A more recent system is one for the construction of the Shasta dam on the Sacramento river, in California. Nearly 10½ million tons of gravel and sand will be required, all being intended for transport on a conveyor system. The sand and gravel are being excavated by a 10-cub. yd. Bucyrus-Monighan walking dragline, assisted by a 5-cub. yd. machine of the same make and type, used for stripping. The sand and gravel, on leaving the treatment plant, wherein it is washed, crushed, and graded, is put into stock piles nearly 10 miles away by means of the long 36-in. belt-conveyor system, which winds its way up hill and down dale, across three railways and five highways. There are 26 flights or belts ranging from 853 ft. to 3,414 ft. in length, forming a total of 20 miles of belting. Some of the flights are down hill and on these the motors are arranged to generate current to assist the motors of the ascending flights. A maximum elevation of 1,350 ft. is obtained, including a climb of 853 ft. in 8 miles. The belt speed is 550 ft. per minute, and the output is 1,100 tons of material per hour. The end-to-end travelling time is 1 hour 40 minutes. Other conveyor systems are used in coal mines and upon the Mesabi iron range. In one iron-ore mine the ore is brought to the surface of the pit, which is 225 ft. deep, by means of three flights of 284 ft. each, set at an angle of 19 deg. 10 min. The belts are 30 in. wide, run at a speed of 350 ft. per minute, and transport 250 tons of ore per hour.

THE UNITED STATES COPPER INDUSTRY.

SOME interesting figures relating to the copper-smelting and refining industry of the United States are contained in a report compiled by Mr. H. M. Meyer, and issued recently by the Bureau of Mines at Washington. This indicates that, during 1940, the production of refined copper from ores mined and smelted at home was 1,880 million pounds, and if to this figure be added the refined copper produced from imported ores and mattes, the total becomes 2,616 million pounds. The corresponding figures for 1939 were 1,409,745,816 lb. and 2,019,030,755 lb., respectively. The production of refined copper from scrap amounted to 232 million pounds in 1940, against 233,225,695 lb. in 1939. Thus the total United States production of refined copper, from all sources was 2,848 million pounds in 1940, this figure constituting an increase of 26 per cent. over the previous year's total, namely, 2,252,256,450 lb. Imports of unmanufactured copper in the form of black blister, converter metal, ores, ore concentrates, etc., during the first 11 months of 1940, totalled 871,739,064 lb., (calculated as copper metal), compared with 672,594,122 lb. in the whole of 1939, indicating that when the figures for the 12 months of 1940 become available they will probably show an increase of 40 per cent. over those for 1939. Exports of copper during the first 11 months of 1940 amounted to 828,509,954 lb., compared with 855,033,814 lb. exported during the whole of 1939. It appears likely, according to the report, that the total for the whole of 1940 will be a little above that for 1939. Included in the total for January to November, 1940, are 693,759,378 lb. of refined copper in ingots, bars and other forms; 40,326,857 lb. of rods; 13,286,209 lb. of old and scrap copper; 7,313,749 lb. of pipes and tubes; 6,698,484 lb. of plates and sheets; 15,468,251 lb. of wire, other than insulated; and 51,657,026 lb. of insulated wire and cable. The largest importer of American refined copper was Japan, which purchased 249,276,881 lb. in 1939 and 225,065,811 lb. in the first eleven months of 1940.

LABOUR NOTES.

UNDER the Essential Work (Shipbuilding and Ship-repairing) Order, 1941, the First Lord of the Admiralty becomes responsible for the efficient use of labour within these industries. The Minister of Labour and National Service will continue to be responsible for the supply of labour from outside the industries—men, for example, who register under the Industrial Registration Order—and for the payment of travelling and lodging allowances. The national control will be exercised at the Admiralty by the Board of Admiralty and a small committee consisting of two employers, and two representatives of the workers will meet from time to time, as occasion arises, under an Admiralty chairman. In the shipbuilding and ship-repairing areas there will be local controls acting under the Flag Officer in Charge of the Port, who, in turn, will be responsible to the Board of Admiralty and, for the purposes of the control, will be given the title of District Shipyard Controller. Under him, the local control will consist of three executives, representing, respectively, naval shipbuilding and repairs, merchant shipbuilding and repairs, and Labour—normally the shipyard labour supply officer, who will be transferred to the service of the Admiralty.

The local control, subject to general direction from the Board of Admiralty, will determine local priorities and be responsible for the day-to-day allocation and interchange of labour in the district so as to provide for an even flow of work and avoid idle time. It will also be responsible for the transfer of labour from one district to another. The control will be assisted by the local technical officer of the Admiralty departments concerned, a representative of the principal labour adviser to the Board and a representative of the Ministry of Shipping. The District Shipyard Controller will be assisted by one or more district consultative committees on which will serve representatives of both employers and workers. It is anticipated that controls will be instituted in the first place in the following places—the list is, however, subject to revision:—Scotland (West Coast), Scotland (East Coast), North-East Coast, Humber, North-West Coast, Bristol and South Wales, London and Southampton, and Cowes.

Explaining the background of the Order in the course of a speech at Newcastle-on-Tyne, Mr. Bevin, the Minister of Labour and National Service, said that he was concerned to avoid a repetition of the strikes which occurred in the last war over the leaving certificate system. Now, both the engagement and the leaving were to be controlled by the Ministry's local officials. Another feature of the scheme was that it would group the men in areas instead of in individual firms which, besides saving time and avoiding waste of labour, would give security of employment and introduce the principle of direction which did not exist in the trade before. Speeding up by interchangeability, the Minister went on to say, was an attempt, not to break down the crafts but to get all the crafts to work as a team, so that at no point was a ship delayed because one particular man was not available to finish a particular job. The men would have a guaranteed weekly wage, so that interchange would not put anybody out of work.

Although all this, Mr. Bevin continued, was for the period of the war only, he did not think we could revert after it to limiting the incoming youngster to follow a narrow, sub-divided occupation. It was not consistent with the group system in education and would induce resentment in the rising generation. Sometimes wrangles occurred between foremen and the men on particular interchanges. There had now to be consultations between managements and men before interchange was determined.

The *Trade Review* of the United Patternmakers' Association states that in February the total number of members in receipt of unemployment benefit decreased by 26 as compared with the figure for January. The number in receipt of sick benefit increased by 41 to 295, and the number of superannuated members from 676 to 677. The total membership is now 13,719. "We have still, however," Mr. Findlay, the general secretary of the organisation, says, "to get another 35 to beat the highest ever recorded," which was given in the November, 1921, *Review*.

In February, the home branch membership of the Amalgamated Engineering Union increased from 455,456 to 464,713, and the colonial branch membership from 40,327 to 41,510. The combined total of 506,223 is probably the highest in the history of the Amalgamation. The number of members in receipt of sick benefit increased from 6,044 to 6,928 and the number of superannuated members from 13,369 to 13,375. The number in receipt of donation benefit decreased from 478 to 382, and the total number of unemployed members from 2,176 to 1,974.

Mr. Tanner, the president, mentions in the March issue of the Amalgamated Engineering Union's *Journal*, that, at a recent conference of representatives of unions with members employed in the engineering industry, the question of trade-union recruitment of refugees was discussed. After reviewing the situation, he says, it was agreed that all Continental workers may be members of the appropriate British trade union. National groups have been established within the framework of the International Federation of Trade Unions so as to retain skeleton organisations in readiness for the return of the men to their own countries. Refugees are to be accepted in the Trade Protection Sections of the British unions, and a collection of their contributions to the national centres will be made independently by these bodies.

A number of interesting questions were discussed at a recent conference in London between representatives of the Engineering and Allied Employers' National Federation and executive representatives of the Amalgamated Engineering Union. One was an application by the union for an agreement regulating the wage rates of apprentices, boys and youths on a percentage basis to the basic district rate, and another an application by the union for the payment of a lieu rate, to all plain time workers, of the average earnings of the pieceworkers in the shop, or payment of a 25 per cent. lieu rate. Both of these applications were made on the instructions of the 1940 National Committee. The employers promised to consult their constituents on the two subjects. A third question discussed related to the rates of men transferred from one district to another. The union claimed that men transferred to a lower rated district should not suffer a reduction in their rate as a consequence. The employers indicated, Mr. Tanner says, their agreement with the general principle of this application, and promised to submit a memorandum covering the matter for the approval of the union.

Writing, obviously, before the promulgation of the Orders of the Minister of Labour and National Service on the subject of the country's man power, the editor of the Amalgamated Engineering Union's *Journal* says:—"When men are tied to their job, they must be satisfied that there is no shadow of a possibility of exploitation, unfair treatment as between one qualified worker and another, or avoidable hardship. Men must be satisfied that they are working for the nation, on essential work, and not for the benefit of private employers. They must be satisfied, too, that the labour of all is fully utilised, and that none is used wastefully or incompetently; that production is continuous and plants are kept running at maximum capacity; and that qualified labour will not be stood off or set on short time whilst denied the right to transfer to full employment elsewhere."

"And what of wages?" the editor asks. "It has been laid down as a cardinal principle," he says, "by the Minister of Labour that 'the rate for the job' will be the basis of wages for war work. But we know that within the framework of union agreements fixing wage rates there are all sorts of variations. Very wide wage differentials have arisen as between one establishment and another in the same district, as well as between one district and another. What about workers earning such differential wages in one place who may be directed to work at another place on a lower scale of payment? It is clearly of the utmost importance that questions like these shall be taken into consideration in applying the new proposals."

Under an award of the National Arbitration Tribunal, the wage rates of women workers in engineering are to be increased as from the first full-pay period following February 16. The national bonus of female workers, 18 years of age and over, is to be increased by 3*s*. a week, that of female workers, 16 to 18 years of age, by 2*s*. a week, and that of female workers under 16 years of age by 1*s*. a week.

SPARE PARTS FOR MOTOR VEHICLES.—In reply to a question, asked in Parliament by Colonel Harold Mitchell, regarding the supply of spare parts for motor vehicles, the Parliamentary Secretary to the Ministry of Transport, Mr. Montague, stated that the Minister of Transport had arranged with the Minister of Supply that civil requirements should be co-ordinated with service requirements. The new arrangement, which would expedite the provision of spare parts for civilian use, was being worked out in detail.

PHOTO-ELECTRIC CONTROL OF BESSEMER STEELMAKING.*

By DR. H. K. WORK.

THE Bessemer process is one of the most interesting methods of making steel, and, at one time, it was by far the most important. In recent years, however, it has steadily lost ground to the open-hearth process. The forces working against the former method of steelmaking are partly economic and partly metallurgical. In this paper, dealing as it does with the control of the process, the metallurgical factors alone will be considered, although it is quite obvious that economic factors must play a part in determining the ultimate status of the Bessemer process. This discussion has been limited in another respect—it deals primarily with the acid-Bessemer process in bottom-blown converters, although much of the information is applicable to basic and side-blown converters. The fact that open-hearth steel has, to a large extent, superseded Bessemer steel has tended to create an impression that Bessemer steel is inferior. This is not strictly accurate; Bessemer steel is actually superior to open hearth for many applications. There are, however, definite metallurgical limitations to the use of Bessemer steel. These result largely from two factors, namely (*a*) the physical properties conferred by nitrogen and phosphorus, and (*b*) the variability from blow to blow. These, of course, are not entirely independent since some of the variability from blow to blow is undoubtedly due to nitrogen. But the variability is also caused by other factors. One of these is the relatively small size of the Bessemer heats. On account of this, a given consignment of Bessemer steel is more likely to contain the product of several heats, each with its own distinctive and slightly-different characteristics, than is the case with open-hearth steel. Added to this is the fact that the refining of Bessemer steel proceeds so rapidly that the timing of the end-point is limited to a matter of seconds, whereas the finishing period in the open hearth extends over a period of one or two hours and the timing of the end-point may vary by several minutes without seriously affecting the product. There is no doubt that this has contributed to the variability of Bessemer steel and has resulted in the use of open-hearth steel in many optional applications.

That Bessemer steel may vary is not necessarily objectionable, and it may even prove an advantage, providing a precise control is available to secure the desired qualities for any specific application. With this in mind, a comprehensive research programme has been undertaken, one phase of which was directed towards securing more accurate control of the blow. The results have been encouraging, and it is the purpose of this paper to describe a method† in which modern scientific instruments, based on photo-electric cells, is currently being employed to assist the blower. The selection of photo-electric cells to control the blow was based on the fact that they are able to give an instantaneous and quantitative record of the flame behaviour, and it was felt that, if suitable points could be found upon which to base the control, the method would be far superior to one relying on the human eye. In spite of the speed of reaction of the eye and its ready adaptability to varying conditions, it has one serious fault—it is not quantitatively accurate. This results from certain inherent characteristics of the eye. It is well recognised in photographic work that the accurate estimation of light values is extremely difficult, as is illustrated by the various tables and exposure meters developed for the assistance of the photographer. This is primarily due to the self-adjusting character of the eye, whereby the pupil automatically adapts itself to light levels over a wide range. In addition, the eye varies from person to person, has a limited wavelength coverage, and is affected by fatigue and by the physical condition of the individual. Even the most careful selection of blowers for their vision and judgment of small changes—and it is reasonable to suppose that the blowers are probably well above the average—leaves much to be desired. Furthermore, the eye produces no permanent record of what has taken place. As a result, it is difficult, if not impossible, to make a scientific study of the flames of a large number of blows to determine the optimum blowing practices. Photo-electric cells do not have these objections, although they retain many of the desirable features of the human eye; consequently, they were resorted to as a basis for control of the Bessemer blow.

Equipment.—After trying a variety of different photo-electric cells and methods for viewing the

* Contribution from the Research and Development Division, Jones and Laughlin Steel Corporation, Pittsburgh, U.S.A., entitled "Photocell Control for Bessemer Steelmaking," presented before the Iron and Steel Division of the American Institute of Mining and Metallurgical Engineers, at the Annual Meeting, held in New York from February 16 to 20, 1941. Abridged.

† H. K. Work, U.S. Patent 2,207,309 (1940).

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flame, the arrangement shown in Fig. 1, on this page, was tentatively selected for use. The preferred field of the viewing element encloses substantially the whole flame at its maximum size. Naturally this also includes areas not covered by the flame, but these do not interfere with the flame reading, if suitable precautions are taken in locating the equipment, on account of the relatively great intensity of the radiation from the flame. It should perhaps be noted that this arrangement does not restrict the radiating area to a given size, and that changes in the flame size affect the readings. Under these conditions it might be thought that the reading would give little information concerning the temperature of the flame and perhaps even less regarding the metal blown in the converter. It so happens, however, that when the flame is at its maximum radiating power the radiation is related to the temperature of the blown metal, so that it is possible to obtain an approximate indication of temperature from the recorded flame curve. The factors favouring the selection of such an arrangement are, firstly, that it tends to average out variations in the flame from point to point; secondly, that the relative size, as well as intensity of the flame, affects the readings, and variations in size are significant; and, thirdly, that approximate information on temperature is obtained at the full-flame reading.

The active element for picking up the radiation is a group of three PJ-22 cells, manufactured by the General Electric Company. This type was selected on account of its suitable range of response, durability, and uniformity, but it is recognised that other cells can be satisfactorily used. The spectral response of this cell is given in Fig. 2, on this page. The transmission curve, when employing an infra-red filter, is shown by the chain-dotted line; the relative sensitivity of the photo-electric cell by the dotted line, and the resultant response of the photo-electric cell, with the infra-red filter, by the full line. Three of the cells are mounted side by side in a housing and set up so that the field of view includes the whole flame. Under these conditions variations in the position of the flame will cause a minimum variation in the reading. The apparatus is set up about 60 ft. from the converter; the exact location is, of course, controlled by mechanical conditions in the shop, such as convenience of mounting on parts of the building; possible interference by cranes or smoke; exclusion of other Bessemer flames, the sun, and the sky from the field of view; ease of servicing, and a variety of other considerations related to the physical surroundings. It is by observing these precautions that the effect of the surroundings on the readings is reduced to a minimum. The response of the cells is amplified and recorded with equipment shown in Fig. 1, so that there is available, so to speak, an autograph of each blow. The importance of this written record cannot be overemphasised, for it made possible a scientific study to determine the best blowing conditions—which could not be accomplished when the changes in the flame were merely qualitatively recorded in the memory of one man.

In order to use the photo-electric cell control most effectively, it is desirable to employ filters on the viewing element. Approximately eighty different individual filters were tried, along with many different combinations of filters, and it was observed that different filters noticeably altered the trace of the flame curve. For example, the effect of "steaming" a blow and the "flash-up" at the beginning and end of the blows are clearly evident when an infra-red filter is used, but with certain other filters the changes are not nearly so pronounced, and may disappear entirely. Furthermore, the selection of the filter has an influence on the clarity with which the end-point of the blow is shown. Hence the selection of the filter is very important. To date, two arrangements have been employed most extensively. The first includes an infra-red filter, the transmission curve of which is shown in Fig. 2, where the response of the photo-electric cell along with the resultant photo-cell filter combination are also given. The infra-red filter has several advantages, namely, the reading is less influenced by smoke or steam between the flame and the photo-cell, the readings are less affected by daylight, and steaming and the end-point are clearly shown. When the infra-red filter was first used, the difference in the response from other filters was noted. The question was raised whether the infra-red radiation of the flame, which was invisible to the blower, followed the same general pattern of the visible flame. To answer this, a series of six photographs were taken simultaneously in the infra-red and visible regions throughout the blow. The result is shown in Fig. 3. In each of the six twin photographs reproduced in Fig. 3, that on the left is the panchromatic and that on the right the infra-red photograph. The upper left-hand pair of photographs were taken 1 minute after the commencement of the blow, the pair immediately below after 7 minutes, and the lower left-hand pair after 8·5 minutes. The upper right-hand pair were taken 10·25 minutes after the commencement of the blow, the pair immediately below after 11·25 minutes, and the lower right-hand pair after 12·90 minutes. Allowing for the recognised limitations in this comparison, due to the sensitivity of the plates and paper, and the fact that the relative exposure was not identical, it is apparent that the flame seen by the photo-electric "eye" and that by the human eye are substantially identical.

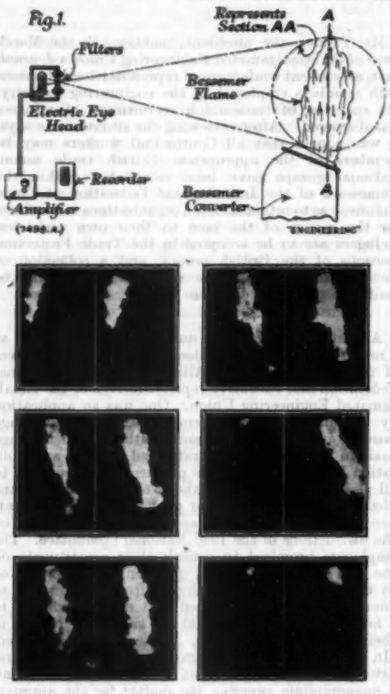


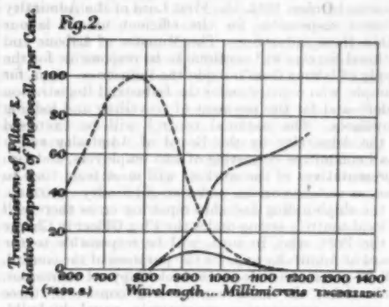
FIG. 3.

Despite the advantages of the infra-red filter, it showed certain unfavourable features when an attempt was made to indicate the end of the blow by an automatic buzzer signal. As a consequence, the infra-red filter was later replaced by a combination of two filters, one of which can best be described as a heat-absorbing filter and the other as an ultra-violet absorbing filter. This combination is now used regularly in the shops and will be referred to in this paper as the "standard photo-cell filter combination." Transmission curves of the filter and the resultant response of the photo-cell filter combination are shown in Fig. 4. The differences between this arrangement and the one using the infra-red filter are that steaming causes a less pronounced drop in the radiation curve, and the end-point falls lower on the curve and varies less in its relative position from blow to blow. In order to show how the response of these two modifications of the photo-electric cell control compare with the human eye, the response curves are given in Fig. 5, opposite. The full line indicates the spectral response of the human eye, the chain-dotted line, the response of the standard photo-cell control equipment, and the dotted line the response of the photo-cell control with an infra-red filter. It will be noted that the infra-red unit covers a range outside the range of human vision while the present standard combination extends over the range of human vision and into the infra-red.

In closing this brief discussion on filters, it probably should be mentioned that, while a workable combination is now available, the study of other filters is continuing, for it is confidently believed that, with increasing knowledge of the subject, it will be possible to select an even more satisfactory combination. The basic equipment required for the photo-cell control unit comprises a viewing head with the three photo-cells, an amplifier and a recorder. These are all strong pieces of equipment designed for shop service, and they have been giving satisfactory results in the works for about two years.

The Flame Curve and its Interpretation.—The equipment for measuring and recording the flame radiation during blowing has been described. This, to be useful, must give information that can be interpreted and related to certain reference points, thereby showing how to control the blow. To illustrate how this is done, a typical flame curve made by the above equipment is given in Fig. 6, opposite, and will be used to indicate what is now known about its significance and how it is employed. The point A indicates the commencement of the blow and since the charts obtained from the recorder read from right to left it is at the extreme right of the curve. Its presence is indicated by a slight rise in the curve which is caused by the converter flame impinging against the shield on the wall of the building. For various studies involving blowing time this is an important reference point. The period of low flame intensity marked A B is generally referred to as the "silicon blow" because, to a large extent, the silicon burns out during this period. B E is called the "carbon blow" for similar reasons, while F indicates the "flash up" at the end of the blow. This will again be referred to below. The relationship between the time A B and the amount of silicon in the iron is given in Fig. 7, which summarises a statistical study of 15,434 blows. It is to be noted that as the amount of silicon increases, the time of the silicon blow increases and that of the carbon blow decreases, but the overall length of the blow increases. That the time of the silicon blow and the total blow should increase is to be expected, since high-silicon contents require a greater amount of oxygen for oxidation and, since there is a relatively constant air flow, it requires a longer time to remove the silicon. The explanation for the shortening of the carbon blow B E which accompanies this change is not so obvious. Of several possible explanations, however, perhaps the simplest is the most satisfactory. Preliminary gas-analysis studies of the exhaust gases from the converter seem to indicate that appreciable quantities of carbon monoxide and carbon dioxide are emitted during the silicon blow, as is shown in Fig. 8. This suggests that the separation between the carbon blow and the silicon blow is not as clear-cut as might be assumed from the flame curve. It also suggests that silicon may repress the luminosity of the flame curve until the silicon is reduced to a fairly low value. Hence, with the longer times designated as silicon blows, more carbon could readily be removed in this period of low flame intensity and the carbon blow shown in the curve would be shorter. Unfortunately, this simple explanation is probably not complete because of certain observed temperature effects which may or may not be related to the silicon content. Nevertheless, this relationship between the flame curve and the silicon of the iron is being used by the blower to help control the blow.

The maximum height of the curve C D (Fig. 6) furnishes information concerning the blown-metal temperature. A statistical study of over 8,000 blows, in which the metal contains normal percentages of sulphur, showed a relationship between C D and the temperature, and indicated that the higher the maximum reading of the flame curve, the higher was the



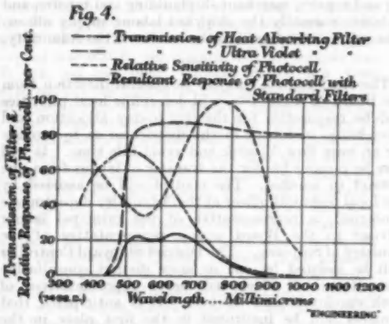


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Fig. 5.

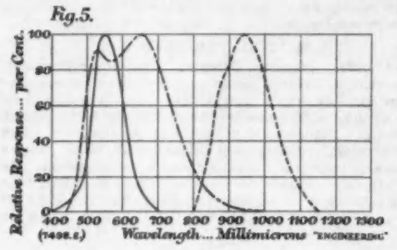


Fig. 6.

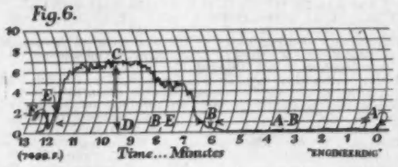


Fig. 7.

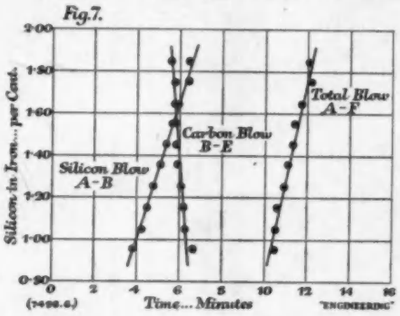


Fig. 8.

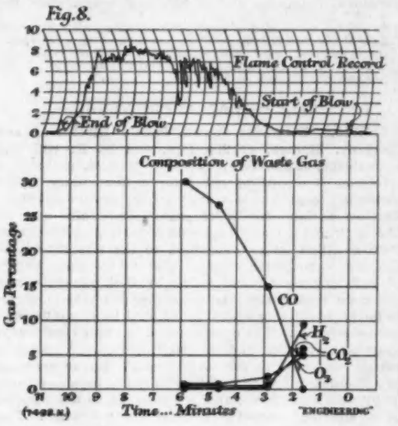


Fig. 9.

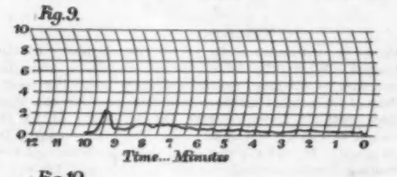


Fig. 10.

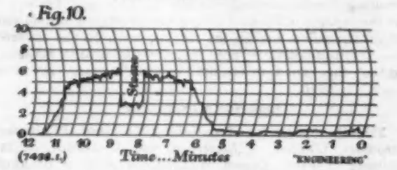
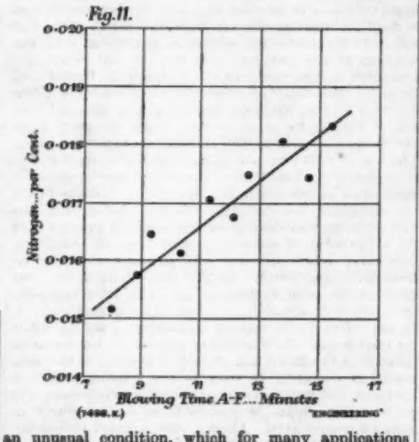


Fig. 11.



blown-metal temperature. The coefficient of correlation between these results, however, is comparatively low, namely, 0·17, indicating that the height of the curve is not a precise measure of temperature. Part of this may be due to the temperature measurements but it is known that the height of the flame curve is affected by other variables; some of them are well recognised. One is the condition of the nose of the converter. The size of the opening, as determined by deposits formed at the mouth of the vessel, affects the results by its influence on the shape of the flame. As a matter of fact, the readings, obtained when the nose is new, may vary so much when compared with those obtained from a worn and enlarged one that it may become necessary to change the resistance units in the amplifier to maintain the readings at a reasonable point on the chart. The number of tuyeres blanked and the air pressure also have an effect, which probably could better be characterised as the effect of changes in the volume of air going through the converter. It will be noted that these variations are gradual in their effect and that, when such is not the case, they are known to the blower. This means that in any small series of blows the relation between the height of the curve and the temperature is more consistent than is indicated by the coefficient of correlation. As a consequence, the blowers are able to use the height of the curve to guide them in handling the heat. This indication of relative temperature is one of the benefits from the photo-electric cell control of Bessemer steelmaking, on account of the effect of temperature on the nitrogen content of the steel.

Before discussing the nitrogen problem, however, it is desirable to consider certain exceptions to the relationship between the temperature and the height of the flame curve. The first of these occurs when the iron temperature and the silicon are both unusually high. Under such conditions the flame curve does not rise to give the typical carbon blow, while silicon persists even to the end of the blow. The unusual shape of the curve, which is shown in Fig. 9, is no doubt related to an effect of silicon in reducing the luminosity of the flame. It is, of course, obvious that a record of this type is useful because it indicates an unusual condition, which for many applications would be grounds for suspicion that the blow was unsuitable. Another interesting effect is obtained when the blow is "steamed"—a practice that is sometimes resorted to to cool a hot blow, although, whenever possible, this is avoided because of a suspected detrimental effect on quality. This is illustrated by the curve shown in Fig. 10. It will be noted that, during steaming, the flame curve is definitely depressed. The extent of this, however, is dependent on the particular filter used in the photo-cell unit. The fact that steaming is now recorded for each blow makes it possible to study the practices of individual blowers and to relate steaming practice to steel quality. Such studies have, in fact, been made and have indicated that steamed blows may be inferior to unsteamed blows. This cannot be accepted as proof that steaming is detrimental, however, since this practice is only applied to blows which are already too hot. Furthermore, a similar relationship has been indicated for the addition of scrap, a practice which by itself would hardly be suspected of a detrimental effect on quality. Hence this point requires additional clarification.

While it is not the purpose of this paper to discuss in any great detail the relationship between the nitrogen content of Bessemer steel and its characteristic properties, the subject is of sufficient interest to justify a brief review. Nitrogen is undoubtedly one of the more important constituents in Bessemer steel, although not much attention has been given to it until recently. Nevertheless, it is believed that nitrogen is largely responsible for hardening and embrittlement on cold working, blue-brittleness, low-temperature brittleness, and strain-ageing—the properties which, to a marked degree, distinguish Bessemer steel from open-hearth steel. Despite the many indications pointing in this direction, however, it is difficult to prove rigidly that the nitrogen alone is responsible for all of these phenomena—some investigators believe that the effects ascribed above to nitrogen are caused by nitrogen in conjunction with other constituents or even caused entirely by the other constituents alone. The subject is further complicated by the fact that the addition of aluminium, titanium, vanadium, and zirconium will cause a tremendous change in the above properties and it is difficult to separate the effects of these materials on the nitrogen from their effects on oxygen and carbon. The problem is a wide and complicated one, but for the purposes of this paper the significant fact is that nitrogen is considered to have a most important effect on the properties of the steel.

It has been indicated that the nitrogen content is related to the temperature of the blown metal and it is interesting to speculate on how the nitrogen is absorbed by the steel. During the course of the blow the nitrogen increases. Nevertheless, the final nitrogen in Bessemer steel is considerably under the saturation value of nitrogen, in pure iron, at steelmaking temperature as determined by Chipman and Murphy.* This would indicate that either some material is interfering with the solution of the nitrogen or that equilibrium conditions are not reached. Considering first the possibility that silicon affects the equilibrium conditions, Vaughan and Chipman† have indicated that silicon has an effect on the equilibrium values but hardly enough to affect seriously the nitrogen content of Bessemer steel. Moreover, Eklund‡ has found that carbon has a marked effect on the solubility of nitrogen in iron and steel. This, no doubt, indicates why pig iron has a relatively low nitrogen content regardless of the temperature. The carbon content, by itself, however, can hardly be said to determine to any great degree the nitrogen content of the finished Bessemer steel, for the solubility of nitrogen in the iron, even at reasonably high carbon values, is considerably higher than that found in the Bessemer steel. It is therefore difficult to escape the conclusion that the equilibrium conditions have not been reached and that factors controlling the rate of reaction are more important than the equilibrium conditions. At the moment it appears that the effect of high temperature is to increase the rate of solution of the nitrogen although it is apparent that other factors also may play a part in the final results.

The question of how the nitrogen exists in the steel is of general interest. At present, there are reasons for believing that it may be present as Fe_2N or possibly Fe_4N, although suggestions have been made that the nitrogen is in the form of complex compounds which include elements such as silicon, or carbon, or combinations thereof, since the behaviour of the constituent, with change in temperature, is not what would be expected for the simple iron nitride. This subject of nitrogen has been given considerable attention here because it is considered one of the important constituents in Bessemer steel, and one of the factors in favour of photo-electric cell control is that, on account of the information derived from the height of the flame curve, it is helping to regulate the nitrogen. Lest there be a misunderstanding, however, the subject of phosphorus should perhaps be mentioned here. Many of the effects attributed to nitrogen can also be caused in part by phosphorus. The practice described in this paper does not control the phosphorus, and other methods of control must be resorted to to deal with this element.

End-Point.—The end-point of the blow will now be considered. As the flame falls at the end of the blow (see Fig. 6), an arrest E occurs. It may vary considerably in shape and position, depending on the steelmaking practice and the filters used in the flame-control equipment. One of the factors that affects the position of the end-point is the sulphur content of the steel; high-sulphur blows, containing added sulphur, show a lower end-point than normal sulphur blows. On the other hand, residual sulphur, over the range of 0·030 per cent. to 0·050 per cent., has no appreciable effect on the end-point. This influence of sulphur, coupled with thermodynamic studies, have led to the belief that the formation of carbonyl-sulphides may possibly be responsible for the arrest in the flame curve. It has become accepted practice to refer to the beginning of this arrest in the curve as the end-point because it has served as a guide to indicate when the blow was ready to turn down. The fact that this arrest occurred regularly at about the same position, when blowing conditions were constant, made it natural to consider it as a natural reference point; in fact, it has assumed a rather mysterious and important significance. By mysterious is meant that its meaning and cause are not clearly understood, but since its use has given good results it is considered important. More recently, when an automatic timing device was installed, it was necessary to use a certain

* *Trans. A.I.M.E.*, vol. 116, page 179 (1935).
† *Trans. A.I.M.E.*, vol. 140, page 224 (1940).
‡ *Jernkontorets Ann.*, vol. 123, page 545 (1939).

fixed flame intensity to start the device. A definite effort is made to keep the blowing conditions such that this point occurs approximately at the regular end-point.

Assuming now that there has been established a certain fixed point, near the end of the blow, which indicates a definite point in the progress of the blow, it is necessary to determine specifically when the blow should be turned down for a particular grade of steel. Theoretically it would seem proper to meter a definite and predetermined amount of air or oxygen through the metal to complete the blow, but this has not proved practical. Variable air leakage in the lines and at the wind box prevents accurate measurement of the air going through the molten metal. Even if this difficulty did not exist there would remain the problem of securing accurate measuring equipment for such large volumes of gas. As a consequence, an approximation has been resorted to, based on the assumption of a reasonably constant air flow, which is known to be not strictly accurate. This consists of allowing a predetermined number of seconds to indicate when the blow for any particular grade of steel should be turned down. For all practical purposes, this procedure has proved satisfactory, providing certain corrections are made. The corrections that are now made in the timing of the after-blow are based on the number of tuyeres blanked, the silicon in the iron, and the weight of the charge. The number of tuyeres naturally affects the air flow. The effect of silicon is less obvious, but this may in some way be related to the apparent effect of silicon on the flame luminosity. The effect of the size of charge is self-evident; less oxygen is required to blow a small charge than a large one, and this would affect the after-blow proportionally.

The number of seconds between the end-point and the point at which the blow is turned down is called the "after-blow"; it is indicated by E F in Fig. 6. The point F is generally referred to as the "flash-back" or "end-of-the-blow" and is caused by the converter flame impinging against the shield on the walls of the building. With certain filter combinations this disappears, but since it is a valuable reference point for checking the after-blow of finished blows a special effort was made to select a filter combination that showed it clearly. As has been indicated, each type of steel requires a specific after-blow, which is determined by statistical studies of the variations in yield and quality with the time of after-blow.

Length of Blow.—The various factors that affect the length of the blow A F (Fig. 6) have been indirectly indicated in the course of the discussion of the flame curve, but will be briefly reviewed here. They are:—(*a*) Weight of the charge; (*b*) silicon of the charge; and (*c*) air-flow pressure and tuyeres blanked. The importance of these factors on productive capacity is, of course, apparent. The blowing time, however, has also an effect on the nitrogen content of the steel. This is shown in a statistical study of some 500 blows, illustrated in Fig. 11, on page 239, which indicates that there is a definite relation between blowing time and nitrogen. It was at first suspected that the silicon in the iron, which has an effect on the length of blow, might be responsible for this, but investigation showed no such relationship. It was therefore concluded that the other factors affecting blowing time must be responsible. That variations in time should affect the nitrogen content is, of course, to be expected. As was indicated above, the absorption of nitrogen, in all probability, has not reached equilibrium and anything giving the reaction more time would cause it to approach equilibrium more closely, thereby resulting in higher nitrogen values.

The author is indebted to his associates in the laboratory who took part in this work. In addition, he would like to acknowledge his debt to Mr. H. W. Graham, whose faith in the Bessemer process made this work possible.

THE INSTITUTE OF METALS.—Among other announcements made at the recent annual general meeting of the Institute of Metals, an account of which appeared on page 214, *ante*, was the statement that the Institute of Metals Platinum Medal for 1940 had been presented to Dr. P. D. Merica, at the British Embassy, Washington, D.C., by Lord Halifax. As is well known, the Medal is usually presented by the President, but, owing to war conditions, this was impossible. The 1941 Platinum Medal, it was further announced, had been awarded to Dr. C. H. Desch, F.R.S., President of the Institute in the years 1938 to 1940. The annual May Lecture of the Institute, the thirty-first of the series, will be delivered in the Clarendon Laboratory, Oxford, at 3.30 p.m., on Wednesday, May 28, by Dr. F. E. Simon, Reader in Thermodynamics at Oxford University. The lecture will be entitled "The Significance of Low-Temperature Research," and it will deal with Dr. Simon's own recent experimental work on the properties of matter at the very lowest temperatures.

"ENGINEERING" ILLUSTRATED PATENT RECORD.

ABSTRACTS OF SPECIFICATIONS RECENTLY PUBLISHED UNDER THE ACTS OF 1907 TO 1939.

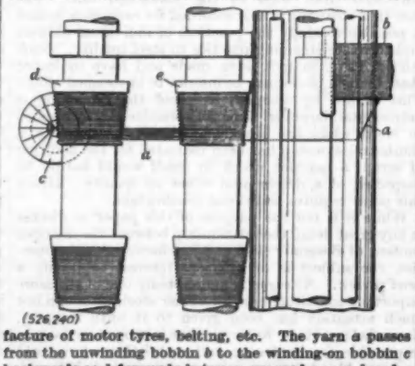
The number of views given in the Specification Drawings is stated in each case; where none is mentioned, the Specification is not illustrated.
Where inventions are communicated from abroad, the Names, etc., of the Communicators are given in italics.
Copies of Specifications may be obtained at the Patent Office Sales Branch, 25, Southampton Buildings, Chancery-lane, London, W.C.2, price 1s. each.
The date of the advertisement of the acceptance of a Complete Specification is, in each case, given after the abstract, unless the Patent has been sealed, when the word "Sealed" is appended.
Any person may, at any time within two months from the date of the advertisement of the acceptance of a Complete Specification, give notice at the Patent Office of opposition to the grant of a Patent on any of the grounds mentioned in the Acts.

ELECTRICAL APPARATUS.

515,213. Diesel-Set Control Panel. Blackstone and Company, Limited, of Stamford, and H. E. Hill and L. Burbidge, of Stamford. (1 *Fig.*) May 23, 1938.—The invention is a control panel for a heavy-duty Diesel engine set consisting of a main engine and an auxiliary starting engine, the latter being electrically started. The main engine is provided with a starting pulley driven from a clutch pulley connected to the starting engine through a magnetic clutch. The fuel supply valves of both engines are controlled by fuel solenoids, and the main engine also has a compression release device to facilitate starting which is operated by a compression release solenoid. The control panel has four electrically-operated switches and a knife switch. A starting switch connected to the control panel can be operated at a distance from the installation, either by an operator or by automatic relay, and is connected to the winding of a starting contactor on the control panel. The knife switch is in parallel with the starting switch and is used for starting the set from the panel. The fuel solenoid of the starting engine is in parallel with the winding of the starting contactor, so that when the contactor is operated the fuel supply is turned on. In series with this fuel solenoid and contactor winding are two sets of contacts, both normally closed. One set is opened by a time-delay relay energised from the battery as soon as the starting contactor is closed. The other contacts are opened centrifugally by the main engine. Thus, if the main engine starts normally and comes up to speed, the centrifugal contacts break the circuit of the starting contactor winding and the fuel solenoid and disconnect the starting motor. On the other hand, if the main engine does not start, the time-delay relay operates and prevents the battery from being run down. At the same time, a red pilot lamp on the panel is illuminated. The delay contacts, once operated, are reset by hand. The magnetic clutch is controlled by a second time-delay relay to allow for the starting of the auxiliary engine. It has a shorter delay than the first relay. The fuel solenoid of the main engine is energised as soon as the starting switch is operated, and simultaneously the compression release coil on the main engine is energised, so that it starts on reduced compression. After a time, a third time-delay relay releases the coil, and the main engine begins to run normally. (*Accepted November* 29, 1939.)

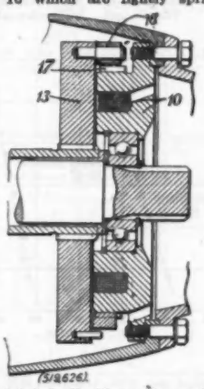
TEXTILE MACHINERY.

526,240. Yarn-Twisting Machine. Tanner Brothers (Greenfield), Limited, of Greenfield, G. Tanner and J. Winterbottom, of Greenfield. (2 *Figs.*) February 11, 1939.—The invention is a machine for simultaneously twisting and stretching yarn so as to produce a cord with a low coefficient of stretch for use in the manufacture of motor tyres, belting, etc. The yarn *a* passes from the unwinding bobbin *b* to the winding-on bobbin *c* backwards and forwards between grooved cones *d* and *e* upon two parallel lines of driven doubling rollers. As the yarn advances up the cones it is stretched so that the yarn which is wound upon the bobbins *c* has a very low coefficient of stretch. The cones are incorporated in the doubling machine itself so that stretching and twisting proceed simultaneously. The extent of stretch to which the yarn is subjected is variable by varying the number of times the yarn passes backwards and forwards between the grooved cones. (*Accepted September* 13, 1940.)



MOTOR VEHICLES.

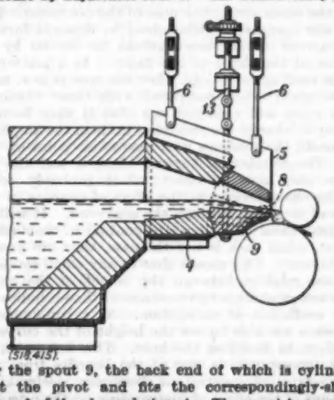
519,628. Magnetic Gearbox. The Rover Company, Limited, of Coventry, and P. A. Scott-Iversen, of Leamington Spa. (4 *Figs.*) August 25, 1938.—The invention is a magnetically-controlled gearbox in which the magnet weight is reduced and fierceness in the change of speed is avoided. A stationary electromagnet 10 of annular form is bolted to stationary casing parts, and one face frictionally engages the armature which is splined to a planet-carrier of an epicyclic gear. The armature 13 carries pawls 16 which are lightly spring-loaded to



engage with ratchet teeth 17 on the periphery of the magnet. When the latter is not energised and the armature is rotating, centrifugal force holds the pawls clear of the ratchet teeth, so that free-wheeling can take place without noise. When the armature is to be braked to change the gear ratio, the electromagnet is energised. By using a relatively light electromagnet the braking torque is small enough to avoid any fierceness in the change of speed. When the armature has slowed down the pawls engage the ratchet teeth on the electromagnet, and positively hold the armature against rotation in the other direction against the main torque. (*Accepted April* 2, 1940.)

MISCELLANEOUS.

518,415. Feeder for Glass-Rolling Machines. Pilkington Brothers, Limited, of Liverpool, and J. Gaskell, of St. Helens. (1 *Fig.*) August 24, 1938.—The invention aims at overcoming the difficulties which result from the erosion of the gates in existing types of feeder, in particular the troublesome removal of frozen glass which leaks through the eroded gaps in the gate. At the front end of the tank is an independent channel piece 4, supported on side frames 5, which are suspended from the superstructure by adjustable rods 6. The frames carry pivots



8 for the spout 9, the back end of which is cylindrical about the pivot and fits the correspondingly-shaped front end of the channel piece 4. The spout is supported by rods 13 threaded at their upper ends, where they pass through worm-driven captive nuts. Thus the spout can be tilted to control the flow of the glass until its bottom is raised above the level of the bottom of the tank, and in this position the glass flow is entirely cut off. The effectiveness of the cut-off is not affected by erosion of the bottom, because its lowest point can always be raised above glass level. This method of control is more accurate than the gate method, and the tilting spout has the further advantage that the glass has an unbroken surface and consequently is more uniform in temperature and freer from impurities due to erosion. (*Accepted February* 27, 1940.)